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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

TRANSACTIONS FOR 1873.

EDITED BY

PERRY F. NURSEY, MEMB. SOC. ENG., SECRETARY.

PLACE OF MEETING AND OFFICES:

THE SOCIETY'S HALL, No. 6, WESTMINSTER CHAMBERS,
VICTORIA STREET, WESTMINSTER.

LONDON:
E. & F. N. SPON, 48, CHARING CROSS.
NEW YORK:
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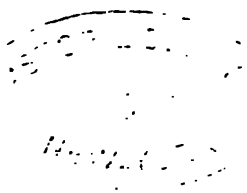

PREMIUMS FOR 1873.

At a Meeting of the Society, held on February 2nd, 1874, Premiums of Books were awarded to:

Mr. WILLIAM HENRY FOX, for his Paper "On Continuous Railway Brakes."

Mr. HENRY GORE, for his Paper "On Horse Railways and Street Tramways."

Mr. S. ALFRED VARLEY, for his Paper "On Railway Train Intercommunication."

Mr. CHARLES JULIAN LIGHT, for his Paper "On a New Method of Setting Out the Slopes of Earthworks."

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SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

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Vice-Presidents.—J. H. ADAMS. T. CARGILL. V. PENDRED.

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PLACE OF MEETING AND OFFICES:

THE SOCIETY'S HALL, 6, WESTMINSTER CHAMBERS, VICTORIA STREET, S.W.

1874.

TRANSACTIONS, &c.

February 3rd, 1873.

INAUGURAL ADDRESS.

By JABEZ CHURCH, President.

A year ago it was my privilege as well as my pleasure to address you upon taking the chair for the fisrt time as the President of the Society of Engineers. The occasion was one of much gratification to myself, for I esteemed very highly the compliment paid me by my fellow-members in being selected to fill the honourable position of President. But whatever feelings of satisfaction—not unmixed with a slight, though, I hope, pardonable, degree of pride—I may have experienced then, such emotions are greatly increased upon the present occasion, when I find myself called upon by the unanimous voice of the Society to occupy the Presidential Chair for a second time.

It is a source of peculiar satisfaction to me to feel—and I trust I may not be considered presumptuous in thus expressing myself—that, by this voluntary act on your part, my conduct, as the chief officer of our Society, has met with your approval. If I have not acquitted myself with so much ability as have some of my predecessors, I yet trust that the material interests of the Society have in no way suffered at my hands. It has always been my endeavour to discharge faithfully the trust reposed in me, and if at any time I may have fallen short of your expectations, and of my own intentions, I trust you will indulgently attribute it rather to want of judgment than to any lack of interest in our common welfare. I have ever fully realized the responsibility of my position, and have endeavoured to act up to it, although no one can be more conscious than myself that I have not always succeeded.

In what I have done I have been ably seconded and supported by the warm co-operation of the Council no less than by that of the members generally, and but for this any endeavours on my part to promote the interests of our Society must have failed.

As in the past, so in the future, I accept the trust you have a second time so kindly reposed in me, and the responsibilities by which that trust is necessarily accompanied, with much pleasure, and with a firm conviction, moreover, that both our Council and our members will extend to me their support, and will not withhold from me their sympathy—their support in carrying on the affairs of the Society to its credit and advantage, and their sympathy, if in a year hence the results do not quite justify their expectations. I am fully sensible of my obligations to the Society, and can only assure you that it will be my constant endeavour to discharge the Presidential duties to the best of my ability, not neglecting, but rather creating opportunities for promoting the substantial progress of the Society. But in opening the Session it is impossible not to recall the memories of some of our fellow-workers who for a while sojourned with us, but who during the past year have ceased from their labours. First on the sad list, although the last to depart, is Professor Rankine, who was one of our honorary members, and whose name stands high and honourably amongst those of men who have advanced the *status* of the engineering profession. Although we can know him no more, his works, which were the result of no common order of intellectual attainment, will remain with us. By these shall we remember the well-stored mind, and recall the genial nature of one who so greatly enriched the engineering literature of his country. Professor Morse, who has done so much in developing our telegraphic system, has likewise passed away, as has also Mr. Augustus Siebe, who greatly improved diving apparatus and the air-pump. The profession and a large circle of friends have had to regret the loss of Mr. W. Bridges Adams, whose many improvements in railway plant and rolling stock, no less than his genial face and cheery voice, will be long and well remembered. Mr. Merryweather, too, who may be considered as the father of the steam fire engine, also passed away at a ripe age, after a lengthened life of honourable toil. Mr. Edward Ladd Betts, the eminent contractor, has left us, as have also Mr. Joseph Pease, and one of his sons, Mr. Gurney Pease, who were both identified with the railway and iron interests. Mr. W. Moodie, whose name will be remembered in connection with the development of the screw propeller, died also. These, and several others in the minor grades of the profession, having executed their allotted tasks, have passed away. But although their places know them no more, their work in the world is being continued silently and effectively by others.

During the past year two incidents have occurred in connec-

tion with our Society, both of which, I trust, will prove conducive to its welfare. In May last the Secretaryship became vacant, and the Council, in the exercise of the power vested in them, sought to fill it with due regard to the interests of the Society. After careful consideration they offered the appointment to Mr. P. F. Nursey—a gentleman who has been a member of the Society for fourteen years, and who at one time held the position of Honorary Assistant Secretary. Mr. Nursey accepted the appointment, and the Council have no reason to wish that their selection had been differently made. The second incident to which I have alluded is the change in our place of meeting. For the last three years we have had our meeting-hall at the Westminster Palace Hotel. The required accommodation, however, could no longer be afforded to us there, as the apartments were needed for the increasing business of the hotel, and it became necessary to provide it elsewhere. The Council have, therefore, taken additional rooms in connection with the Society's offices, and have carried out certain alterations, whereby a large meeting-hall has been secured to the Society, which will doubtless meet our requirements for many years to come; and I have no doubt that many advantages will accrue to the Society from having its offices and hall *en suite*.

Another matter for congratulation is, that during the past year two volumes of our Transactions in arrear have been published, and copies forwarded to the members, whilst a third volume will shortly be issued from the press. This will be followed by the volume for last year, after which the Transactions will be published annually and with regularity.

In other respects the prospects of the Society are decidedly encouraging, as the list of candidates for membership just read, and that of those who will presently be balloted for, testifies.

Another matter to which I would call your special attention is the reading of papers, which is of paramount importance to the Society—they are, in fact, the fruits by which it is known. In pressing this matter upon you I can but reiterate the sentiments that you have previously heard from this Chair. I can only say that it is not necessary that a paper should be lengthy. A short practical paper will often lead to a discussion in every way as valuable to the members as a long one. The value of a paper is by no means to be measured by its length, although lengthy papers may prove most valuable. I am the more desirous of impressing upon members the fact that a short paper is most acceptable, because it is by no means an uncommon notion that a paper and an exhaustive treatise are synonymous terms. In other words, members often decline to write papers, alleging that they have not sufficient time to devote to the

subject, their idea being that unless they study for it, read it up, and say everything that can possibly be said about it, the paper will be of no value whatever. But the fact really is that a short practical paper, followed by a good discussion, which it is sure to evoke, is often of more real value to members than long papers of a theoretical or speculative nature, which there may be neither time nor inclination to discuss. I trust I shall be excused for having detained you somewhat upon this point, but I feel that it is of the utmost consequence to the Society that we should do our best to impart to each other the special knowledge we ourselves possess, and to enrich our Transactions with valuable contributions. If any guide be wanted in this matter I trust it will be supplied by the circular upon the present subject recently issued; and if any incentive to action be required beyond that of the Society's good, I trust it will be found in those mute yet eloquent tokens of merit, the premiums which I have just had the pleasure of presenting to the authors of the best papers read during the past year.

In urging these matters upon your notice in the way I have, I trust it will not be considered either out of place or tedious. I have done so in discharge of one of the duties inseparable from my position amongst you—namely, that of promoting our common interests by counsel and advice upon points on which it is plainly needed. It is a duty which cannot be evaded consistently with the professions previously made by me, and it is necessary further in the interests of each member, as leaving him no escape from his appropriate individual responsibility.

Having said thus much concerning the chief matters upon which depends the progress of our Society, I purpose in the next place to review generally what has taken place in connection with the Society during the past year. The first paper read was by Mr. Vaughan Pendred, who chose for his subject recent examples in American locomotive practice. The engines described and illustrated by Mr. Pendred were selected from the Louisville and Nashville Railway, and the paper was very interesting, as illustrating various points of difference between American and English locomotive practice. Two features especially were brought prominently before the meeting by the author, and these were the swing-bogie frame and the ingenious manner in which the leading end of the engine is carried, and by which arrangement a considerable amount of lateral play is obtained.

This paper was followed by one from Mr. George Spencer, upon a subject which has undergone some discussion in the public papers during the past year—namely, State Railways and Railway Amalgamation. Mr. Spencer did not consider that

it would be of any advantage to the nation if the railways of this country were taken and managed by the State. He was, however, in favour of amalgamation where circumstances clearly indicated the advantage of such a course to the companies without prospect of danger to the public interests. For my own part I fail to see the advantage of railways becoming State property, especially when it is remembered that the railway capital of the country amounts to about 600,000,000*l.*, the whole of which sum has been raised by private enterprise.

The next paper was by Mr. E. G. Bartholomew, on a subject he was particularly qualified to deal with—"Electric Telegraph Instruments," and which he treated in a very comprehensive manner. Mr. Bartholomew considerably added to the interest of his paper by exhibiting a fine collection of telegraph apparatus in use from the earliest period of the practical introduction of the system down to the present time. The more modern examples were shown in operation by the author, who had provided battery power for that purpose. Mr. Bartholomew traced the history of telegraphic apparatus from the earliest time down to the present, describing in detail the progressive improvements which had been made. The author showed that the principles of construction remained the same throughout, although great alterations had been made in points of detail. Altogether the paper was one of the most interesting read during the session.

At the first meeting after the recess Mr. Bartholomew again occupied the attention of the members by a paper on "Telegraph Batteries." In this paper the author once more afforded a large amount of interesting information upon the subject of telegraphy. It is the third paper with which he has favoured the Society, he having read one on "Telegraphic Conductors" in 1869. It will be seen therefore that in these three papers Mr. Bartholomew has laid the subject of telegraphy completely before the Society, comprising as they do descriptions of the conductors, the instruments, and the batteries. In this last paper the author very aptly compared the electric telegraph to the steam engine, the battery representing the boiler, the conductor the steam pipe, and the instrument the engine. He then went on to describe the different kinds of batteries, and the principles of their construction, and he graphically explained the laws by which the force generated was governed, pointing out that that force was proportionate to the chemical action and to the consumption of some of the elements of the battery. He showed the necessity for preventing any such action or decomposition from going on unless the resulting force was utilized. It was further shown how, by rendering the

surface of the most oxidisible metal homogeneous, local action was suppressed. The various methods of joining up the elements, whether as forming one large plate or in series, were described, and the resulting character of the force explained. For these papers the Council have awarded Mr. Bartholomew a premium.

This paper was followed by one on "Milford Haven and its New Pier Works," by Mr. H. Davey, wherein he first pointed out the natural advantages of the Haven, which made it one of the best harbours in the world. Although there is a fall of 22 feet at spring tides the largest fleet can at all times find shelter and security there with good working room. The area of the main portion of the estuary from Blackhouse Point to Cosheston Pill above Pembroke Ferry is 8810 acres at high and 6855 acres at low water. At one fathom deep at low-water spring tides it is 5354 acres; at three fathoms it is 4245 acres, and at five fathoms it is 2951 acres. Mr. Davey told us he considered that the great rise of tide offered every advantage for the construction of graving docks in the port. He also advocated the extension of piers and engineering works for ship accommodation in the Haven, his reason being that the estuary, from its geographical position as well as for other important reasons, was admirably adapted for an extensive export and import commerce. In this conclusion those who are in the least acquainted with the Haven will agree with Mr. Davey; and I may here mention that in the early part of last year a movement was started for the purpose of constructing docks at Milford of such a size as to provide accommodation at neap tides for a class of vessels similar to the 'Spain' and other new steamers belonging to the National Steam Ship Company. It is stated that vessels of this class could make to New York two more voyages per annum from Milford than from Liverpool. The necessary Parliamentary powers by which the construction of the works may be proceeded with are in existence. The engineer of the proposed works estimates the cost at about 600,000*l*. Mr. Davey in the paper under notice described the New Iron Pier at Newton Noyes, which runs out from the mainland into deep water. It is provided with three lines of rails, and is connected with the Great Western Railway at Milford station by means of a short line running along the north side of the Haven near the foreshore. The main portion of this pier is 600 feet long and 50 feet wide, supported on four rows of wrought-iron piles in 20 feet bays. At the outer end a length of 180 feet is built at right angles with the main portion, the construction being similar. The pier is provided with hydraulic hoists, cranes, capstans, &c., and has every arrange-

ment for the convenience of shipping. The details of these mechanical arrangements were fully illustrated by working drawings, and the paper will prove most valuable for reference when published in our Transactions. For this paper the Council awarded Mr. Davey a premium.

The last paper of the year, and one of the most practical, was on Continuous Railway Brakes, by Mr. W. H. Fox, who in the first place considered the conditions which a continuous brake should fulfil. He then investigated the retarding force required to stop a train within a given distance, which he showed varied greatly under the differing conditions of railway traffic. His general conclusion, however, was that a retarding force of 18 per cent. of the weight of a train travelling at the rate of 60 miles per hour would stop it within a distance of 220 yards in ordinary weather. Mr. Fox then gave his views with respect to wood *versus* cast-iron brake blocks, which were to the effect that cast-iron blocks were the better of the two, because with them the friction was more constant than with wood blocks, and was higher in foggy and wet weather, just the precise time when brake-power is most needed. The author then proceeded to describe, by the aid of some elaborate diagrams, the Chain Brakes of Messrs. Wilkin and Clarke, and the Hydraulic Brake of Mr. Barker, pointing out the relative advantages and disadvantages of each system. The author's general conclusions upon the subject of brakes were that every locomotive and carriage should be fitted with sufficient brake-power to enable a train running at the rate of 60 miles per hour on a level line to be brought to a state of rest within a distance of 220 yards in ordinary weather. For this carefully-prepared paper the Council have awarded to Mr. Fox a premium. The author by no means exhausted the subject of continuous brakes in this paper. To have included all would have been to extend the paper beyond reasonable limits. He therefore reserved the consideration of the Atmospheric and Electric Brakes for a second paper, which he has kindly promised to bring before the Society at our next ordinary meeting.

It will be seen that the subjects of the papers read during the past year have been as varied as the papers themselves have been interesting. But these papers possess an interest beyond that of the passing hour; as practical productions they will have an abiding interest in our Transactions, where they will doubtless prove profitable to those of our members who reside out of London, and who consequently cannot attend our meetings. Besides this, they will unquestionably prove valuable for reference, even to those who heard them read. They have led, for the most part, to animated and useful discussions, and each

author has well merited the vote of thanks given after the reading of his paper.

I next turn to the interesting and instructive visits which were made by our members to various engineering establishments during the recess. I believe that to our Society is due the credit of originating visits to public and other works, and I can conceive no better method for acquiring practical and often really valuable information. Useful as are our papers, and instructive as are the discussions upon them, there is superadded to these advantages that which must ever accrue from ocular demonstration and actual inspection of work. It is therefore a satisfaction when we find members taking advantage of these visits, which are always rendered pleasurable by the absence of that restraint inseparable from a scientific meeting. In my address last year I suggested that members should make notes of what they saw, and prepare a short paper upon the subject of each visit, for the information of those who were unable to join the inspecting party, as well as with the view of discussing the merits or demerits of the works or processes inspected. This suggestion does not appear to have been acted upon; so, with a view of obtaining the object I have indicated, and also of placing on record, and of disseminating, by means of our Transactions, information respecting these visits, I now propose to give a brief account of each.

Our first visit was made to the Royal Gun Factories, Woolwich, permission having been kindly accorded by Colonel Campbell, R.A., Superintendent of the Gun Factories. The first point of interest visited was the forging department, where, as also in the other shops, Colonel Campbell had made arrangements for illustrating the processes involved in the manufacture of the Woolwich guns. In the forge we witnessed the coiling of a bar of iron 135 feet long, for a 10-inch 18-ton gun. Under a steam-hammer close by was a small coil for tubing a cast-iron gun on the Palliser principle, a number of those guns being then in course of conversion from smooth bore to rifled pieces. Near at hand was a 15-ton steam-hammer working up a trunnion coil for a 10-inch gun, a muzzle coil being wrought at another hammer close by. From the forge we were conducted to the olling-mill, where the chief feature was the rolling of the 3-inch rs from which the coils are made. The next process illus-ted was the shrinking of a breech coil on the steel tube of a nch gun. In this process the coil is brought up to a dull eat, and lov the tube, within which a stream of ept pl pon which the coil shrinks in cooling. we number of 35-ton guns in various Ve were then conducted over the

turneries, the boring department, and the pattern-room in succession, in each of which we found the various processes being carried on by the aid of some of the finest machinery in the world. We next went over the shell foundries, where we saw Palliser projectiles in every stage of manufacture, from the moulding to the studding and finishing. In order to prevent rust, these shells are lacquered inside with a resinous composition, after which each shell is subject to an hydraulic test of 100 lbs. per square inch. We were subsequently conducted over the laboratory, where we witnessed the series of highly interesting processes connected with the manufacture of the service cartridges.

About a month later we visited the Locomotive Works of the London, Chatham, and Dover Railway, at Longhedge, Wandsworth. In the absence of the Locomotive Superintendent, Mr. Martley, who is one of our members, we were conducted over the works by his deputy. The fitting-shop here is a spacious building 250 feet long by 45 feet wide, and contains a variety of excellent planing, drilling, slotting, and bolt and nut cutting tools, by Sharp Stewart, Whitworth, and other makers, which were seen at work upon the details of four new locomotives which the Company were then building. The turning-shop, which is under the fitting-shop, and of the same dimensions, was next visited, and then the brass-finishing shop, the pattern-making shop, and the smith's shop in succession. The Company's Foundry is at Dover, and there the principal castings are made. The erecting-shop is another large building about 150 feet long by 50 feet wide. Engines for repair are brought in at one end upon a steam-moved traverser, which carries the engine "side on" down the shop to any one of a number of sidings arranged on either side of the building. The carriage shop is a building 200 feet long by 120 feet wide, and adjoining it is another large shop containing a set of wood-working machines. The whole of the machinery is driven by a pair of engines of 40 horse-power each, with high and low pressure horizontal cylinders. The Longhedge Works afford employment to about 800 men, and they are very well arranged for their chief requirement, which is that of repairing.

At the end of August the members paid a visit to the Works of the Ransome Stone Company at East Greenwich, over which they were conducted by Mr. Frederick Ransome, the Managing Director and inventor of the beautiful process of making artificial stone carried on there. This process consists of mixing together sand and dissolved flints in certain proportions, and in hardening the composition by chloride of calcium. We first saw the sand in the course of being dried in an apparatus designed

for the purpose; then we were shown the digesters in which the flints were being dissolved by the action of caustic soda under steam pressure, for the production of silicate of soda. From the digesters we were conducted to the incorporating mills, where the sand and silicate were being mixed into a plastic material, which we followed to the moulders' benches, and thence to the chloride of calcium baths, and subsequently to the washing and drying departments. We were also shown some excellent samples of stone produced under Mr. Ransome's new process, by which the chloride of calcium bath and the subsequent washing are dispensed with. This result is effected by the use of Farnham stone as one of the ingredients, the stone possessing the peculiarity of being soluble at a low temperature in a solution of caustic soda.

Upon quitting Mr. Ransome's interesting works we visited those of the Bessemer Steel and Ordnance Company close by. These works were being laid out for the manufacture of Bessemer steel and of ordnance made from that material. The works were well arranged, and it is purposed to accept the invitation of the Bessemer Company, given at the time of our inspection, to revisit them next vacation, when they will be completed.

The last of the vacation visits was to the works of the Great Eastern Extension to Broad Street, and the Locomotive Works of the North London Railway at Bow. Some idea of the magnitude of the Great Eastern Works may be gathered from the fact that the station at Broad Street will cover an area of 9 acres. It will have a frontage of nearly 300 feet, and will be laid out with eight platforms covered in by an iron and glass roof in four spans. The ground has been cleared and the lower portions of the side walls have been built in excavated trenches, leaving a mass of earth 9 acres in area and 15 feet deep to be removed. The platform level will be 11 feet below the level of Broad Street, and will be approached from the roadway by an easy incline. From Broad Street the line will be carried on the level for about three quarters of a mile to Brick Lane, where it passes under the existing viaduct of the Great Eastern main line. From Brick Lane the line has a rising gradient of 1 in 70 to its junction with the main line at Bethnal Green. The construction of this extension line involved the diversion of the high-level sewer which intersected the route, but which has now been carried direct from Norton Folgate under Bishopsgate Street to Gracechurch Street, where it rejoins the main sewer.

At Bow we found our past President, Mr. W. Adams, waiting to conduct us over the works of the North London Railway, of

which line he is the locomotive engineer. The shops of this Company are twelve in number, and are arranged on either side of the Company's line to Blackwall. They comprise turning, fitting, and grinding shops, erecting shops, boiler shops, carriage building and repairing shops, smiths' shops, and carriage and engine sheds. As the Company build nearly the whole of their engines and carriages, the members had a good opportunity afforded them of acquainting themselves with locomotive and carriage construction in all their departments. Various matters of interest were brought under notice in the shape of labour-saving machines, of which there were several, amongst them being a machine for finishing the outside of engine cylinders, and also for re-boring them without removing them from the engine. After quitting the shops we were shown a very ingenious arrangement of an electric brake attached to a train of carriages about to be worked experimentally on the North London Railway. As this brake will be described in a second paper on Continuous Railway Brakes, shortly to be read by Mr. Fox before our Society, I shall only briefly refer to it here. It consists of a very simple arrangement of powerful magnets excited by batteries carried in the carriages and in the guard's van, the power produced being utilized in putting on the brakes. The power is applied instantaneously and with ease, and is taken off with equal rapidity. Should a train break in two the severance of the connection causes the brakes to be applied automatically both in the forward and rear portions of the train.

Before quitting the subject of these visits I wish to impress upon members the importance of attending them. Much excellent practical information is always to be gained, besides which they afford an opportunity for pleasant social intercourse, by which the bonds which unite us together as members are more closely cemented. By the introduction of friends, too, at these inspections, the strength of the Society has often been augmented. I trust therefore that at our future gatherings of this nature, as well as at our ordinary meetings, we shall have attendances which indicate that a real interest is taken in our Society, for it must not be forgotten that the attendances are the true index of the interest felt by the members. If I am urgent in pressing these matters upon you it is because I am earnest. Moreover the only direct opportunity a President has for placing his views before the body of the Society is through the medium of his Inaugural Address. As I believe the views I have expressed, if acted upon, will benefit the Society as a body, as well as its members individually, I do not hesitate to state them plainly and to impress them strongly, asking your in-

dulgence if I am tedious, on the ground of my earnest desire to discharge the obligations to the Society under which my office as its President places me.

My observations hitherto have related solely to matters in which we are all more or less directly concerned as members of the Society of Engineers. Let me now turn to those subjects which possess an equally direct interest for us as members of the profession our Society represents. And in so doing I would first draw your attention to the progress made during the past year in matters connected with that branch of the profession in which I am specially engaged—Sanitary Engineering.

Undoubtedly the disposal of sewage is the most important question in connection with this subject, and although it has not yet received a permanent practical solution, sufficient has been done during the past twelve months to lead to the hope that the attainment of the desired object is not very far off. The varying physical features of localities in which the question of the disposition of sewage has to be solved, as well as other attendant circumstances, render it necessary to adopt various modes of treatment. Thus we have the irrigation, the filtration, and the precipitation processes. In the first-named process we have one the success of which in every respect has long since been established. Not so, however, with the second—filtration—which in hot weather becomes a nuisance, and by which the manurial ingredients are wasted. But, successful as irrigation is, there are many cases in which the system cannot be applied, and which are therefore dependent upon precipitation for affording the means of showing a clean bill of health. With precipitation, however, a difficulty has hitherto been experienced in dealing with the accumulation of sewage, and wherever any of the precipitating processes have been in operation for any length of time large deposits of undried sewage are the invariable result. But the insurmountable difficulty has been how to convert it at a cheap rate, and in a convenient manner, into a dry powder, fine enough to be used for agricultural purposes, and without having to undergo a separate grinding process. Numerous attempts have been made to solve this problem of drying, and the result has been that the cost of manual labour alone has amounted in some cases to nearly as much as the value of the dried manure, whilst in others it has exceeded it. During the past year, however, a mechanical process has been introduced into practice, and, so far as the drying is concerned, has produced satisfactory results. This process, which is the invention of Messrs. Milburn and Co., consists in drying the solid sewage on a hot hearth, which the whole of each charge is made to traverse. The machine in which this is

mplished consists of a floor formed of iron plates which are
d by a fire placed under the feeding end, the heated pro-
of combustion passing under the drying floor throughout
whole length. Over the bed is a frame extending nearly
length of the floor, to which is fixed a series of transverse
, the edges of which rest on the floor and act as scrapers.
the top of this frame at each side are three bracket pieces,
having a vertical slot in which work crank pins, the
nks being attached to gearings placed on either side of the
chine, all being arranged to revolve together. The slots
equal to the full length of the stroke of the cranks, so that
each revolution the frame is moved to and fro, and the trans-
se bars scrape the whole surface of the bed and prevent the
wage from caking. The length of the slot can be regulated
by an adjusting piece, and according to the extent to which the
slots are contracted, so is the frame lifted at its backward
movement. The scrapers then pass over a portion only of the
wage, and at the return stroke each scraper passes a portion
on to the next scraper, and thus the sewage travels the length
of the bed until it comes off dry at the end in the form of
powder. Between the scrapers and fixed to the movable frame
is another series of transverse bars which serve as pulverisers.
They are fixed at varying heights above the plate, but do not
touch it. At the inlet end of the machine they approach
within 1½ inch of the plate, this distance gradually diminish-
ing with each until the last one at the delivery end very nearly
touches the plate. As the sewage passes over the plate these
pulverisers break it up, and as it dries they finally reduce it to
powder. Besides these pulverisers, which are fixed to and
travel with the frame; there are others which are stationary.
These are transverse bars fixed to the sides of the machine and
carrying a series of prongs which assist to break up the mass of
sewage as it is moved to and fro. They are used at that point
where the sewage begins to stiffen and assume the consistency
of clay. The products of combustion from the fire after passing
under the plate are conducted over it and are carried away by
a chimney along with the vapours arising from the drying
process. It is alleged that some practical trials with this
machine at the Borough Sewage Works, Leicester, show that a
profit is obtainable from sewage thus treated. The furnace of
an apparatus capable of drying 28 tons of sewage in 24 hours
requires rather less than a ton of slack coal for that purpose.

The next proposition for solving the sewage problem that
has been advanced during the past year is that of Major-General
ott, C.B., whose process consists in clarifying sewage by means
lime, and converting the deposit into cement, or into agri-

cultural lime. This process has been for some time past in operation at Ealing, which has a population of 10,000, is efficiently furnished with water-closets, and has a daily sewage flow ranging from 350,000 to 400,000 gallons. The precipitating materials—lime and clay—are mixed in certain proportions and are introduced into the main sewer at a point about a mile above the works. No deposit whatever is created in the sewer, which, on the contrary, is found to be kept particularly clean. On reaching the works a little more lime and clay is added to the sewage if necessary, and it is conducted to precipitating tanks, of which there are two, in a well-ventilated building. The sewage passes slowly through the tanks, percolating upwards through a filter of sand and gravel into the open air. The water being run off from the tanks the precipitate is allowed to escape through apertures at the bottom and is subsequently removed and dried on a floor of hot plates. Here the mud becomes converted into blocks, containing about 30 per cent. of organic matter. These blocks are then placed in a kiln and burned, very little fuel being required, the organic matter greatly assisting combustion. The calcined material is removed to a mill, where it is pulverised and forms a cement. The quantity of lime and clay required for treating 1,000,000 gallons of ordinary sewage is $1\frac{1}{3}$ ton of the former, and $\frac{2}{3}$ of a ton of the latter material. The result is rather more than 2 tons of cement, and the profit is stated to be 10*s.* per ton. This estimate does not include wear and tear, nor interest on capital, neither on the other hand is the bulk of the mineral obtained from the sewage taken into consideration.

The third method of dealing with the question under consideration has been lately brought forward by Mr. James A. Manning. The process consists in the deodorization and subsequent concentration by heat and chemical agency of the matter taken from the houses, so as to produce a dry pulverulent manure, which is stated by the inventor to rank with the highest class of artificial manures, and to be worth in the market from 8*l.* to 12*l.* per ton. Existing cesspits are to be filled up, and in their stead portable receptacles are provided. These receptacles are changed every few days, and each one, when supplied, contains a powerful deodorant, so as to prevent decomposition and to fix the nitrogen. The formation of carbonate of ammonia is said to be prevented, and the fertilizing value of the material secured. The full receptacles are taken to the Works and emptied into a hermetically-closed stowage reservoir, fixed at such a level as to admit of an easy flow into the evaporating chambers. These chambers are built of fire-brick, having flues underneath, and at each side, with a heated current passing over

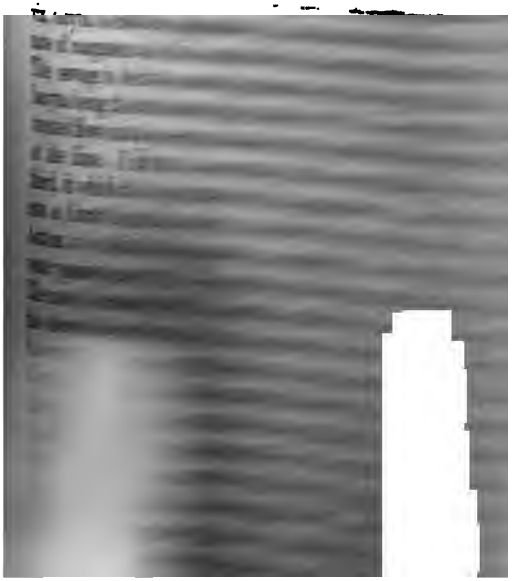
the top of the contents. At the same time, the material is agitated by mechanical means, to prevent burning or charring. The vapours and smoke from the furnace are drawn off by an exhaust, and are forced into a condenser, where ammoniacal liquor is formed, which is afterwards run into evaporating pans and treated chemically. The sulphate of ammonia then crystallizes, and is collected for the purpose of mixing with the manufactured manure, if required, or it may be sold separately. From 15 to 16 tons of the solid and fluid matter collected from the houses is said to yield about one ton of dried powder, in which the whole fertilizing power of the larger quantities is said to be concentrated. The result of this process is stated to be highly satisfactory in a commercial point of view, the cost being only about 4*l.* per ton. The system has been tried at Bloxwich, in Staffordshire. It will be seen that it is mainly applicable to towns where only a partial system of sewerage exists.

The most recent proposition for the recovery of manure from ordinary liquid sewage is that of Mr. Adolphe P. Vassard, the principles of whose process were only promulgated towards the close of last year. Mr. Vassard's primary object is to obtain a valuable manure, his secondary object being to render sewage innocuous. To effect this the inventor uses three materials—viz. baryta, soluble phosphate of lime, and a solution of carbonate of magnesia, which are added to the sewage in succession. The sewage is first coarsely strained and run into a tank, the baryta being then thoroughly mixed with it. The sewage thus treated flows into a second tank, where it is mixed with a solution of the lime. From the second tank the sewage flows into a third, in which it is treated with the magnesia. It is now run into a fourth tank, where it is allowed to settle, and in the bottom of which the manure is deposited, the clear effluent water passing away. The deposit is finally removed and dried. The novel feature in Mr. Vassard's process is the use of baryta, the chemical action of which is similar to that of lime. Baryta, however, being stronger than lime, has a more rapid and effective action than the latter material, although it requires about three times as much baryta as lime per gallon of sewage treated. A series of careful experiments have been made by practical chemists, who have treated by the above process sewage taken from the Abbey Mills Pumping Station. The results are stated to be highly satisfactory, and to demonstrate most clearly that the process is exceedingly perfect, and that by it an excellent fertilizer is produced at a much smaller cost than that at which manure is manufactured by any other known process. It is, however, wanting in potash and soda, which can be added to the dried deposit. Judging from the reports which I have seen

respecting this process it bids fair to be a success. At the same time the fact that baryta is a poisonous substance must not be overlooked, as it would necessitate the process being carried on under certain restrictions. The manure thus prepared might have a deleterious effect upon vegetation, while the effluent water might possibly injure the streams into which it flowed, although the baryta might be rendered insoluble by the sulphates in the water.

Another matter of importance in connection with the sanitary condition of the Metropolis is worthy of note, and that is the opening by the Lambeth Water Works Company of a new intake from the Thames, at West Moulsey, in August last. Complaints about the quality and quantity of the water supply in the Metropolis were at one time very frequent. For some time previously the water of the Lambeth Company had been deteriorating, principally in consequence of the increase of town drainage flowing into the Thames above Ditton, where the reservoirs are situated, and also because of the polluted current of the Mole flowing into the Thames. The Rye also, higher up the stream, brings down its quota of discolouring matter. The result was the construction of a new intake about a mile above the town of Hampton, the water being conveyed to the reservoirs by a conduit 3½ miles long. The brick portion of this conduit is of oval section 5 feet 9 inches high and 4 feet 9 inches wide internal dimensions; the remaining portion is composed of iron pipes 4 feet 6 inches internal diameter. There are two lengths of these pipes, respectively 800 yards and 550 yards long, laid through East Moulsey and Thames Ditton, as a security against the leakage into the aqueduct of any foul subsoil water. The conduit for the first mile is laid level and then with a gradual inclination of 3 feet, giving an average fall of 12 inches per mile throughout. Thus by the force of gravitation the water will flow at a velocity sufficient to deliver 20,000,000 gallons per day. The conduit in its course is constructed at depths varying from 10 to 30 feet below the ground surface. The fall of the Thames between the points of inlet and discharge varies from 7 to 8 feet, according to the state of the river, and as 3 feet only of this is required to give the requisite flow through the aqueduct there remains a gain of from 3 to 4 feet additional head of water at the Ditton reservoirs. As the Lambeth Company supplies about 48,000 houses, containing some 350,000 inhabitants, the advantage, in a sanitary point of view, of permanently improving the water is very great.

While on the subject of water supply, it may prove interesting if I place before you a few statistics relating thereto. The quantity of water supplied to London by the several companies



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et, it was 1 in 17. On the
foot of Skinner Street to

Snow Hill, a length of 301 feet, the gradient was 1 in 22, and to Angel Court, a length of 238 feet, it was 1 in 25. The steepest gradient is now 1 in 48, and this extends from Fetter Lane to the western side of the Viaduct Circus, a distance of 250 feet. From the Circus to Newgate Street, the whole line of the Viaduct is practically level, the principal gradient being 1 in 200. The best gradient on the old route was 1 in 66. It is calculated that a horse can draw a moderate load at a trot up a gradient of 1 in 40 with ease, so that even the Fetter Lane gradient comes well within this limit, and it only constitutes 250 feet out of a length of 1695 feet. The whole of the foundations of the Viaduct are carried down to the blue clay, and are formed upon beds of concrete. The foundations of the Farringdon Street bridge are carried down to a depth of 13 feet below high-water level. The Viaduct is 80 feet in width, 50 feet being occupied by the carriage-way and 30 feet by two foot-paths of 15 feet each. There are several remarkable features in the Viaduct besides the Farringdon Bridge, but which are wholly out of sight. The central portion of the Viaduct, between Snow Hill, and the Circus, is carried on a series of arches 21 feet span and 45 feet deep, forming a range of vaults approached by a line of carriage-way formed in the body of the structure and running the whole length of the vaults. These vaults are well ventilated and drained, and have entrances from Farringdon Street and Shoe Lane. Under the footways of the Viaduct and flanking the vaults, are two subways, carrying pipes for gas, water, and telegraph wires, while beneath each of these subways is the conduit for the sewage of the district, which flows through an open channel, flanked by a paved foot-way, and carried on the concrete foundation. The construction of this fine work was not carried out without interruptions, inasmuch as Shoe Lane, Farringdon Street, and the London, Chatham, and Dover Railway have interfered with the continuity of the substructure, while the tube of the Pneumatic Dispatch Company has been laid in some places beneath the foundations of the Viaduct and in others above them. Besides the Viaduct there is Charter House Street, with a length of 455 feet and a width of 60 feet on a gradient of 1 in 43; the route from Snow Hill on to the Viaduct, which is 665 feet in length, on a similar gradient; and the new street from Shoe Lane to the Viaduct Circus, all with their underlying sewers and vaults. These, with sundry other works, combine to form one of the finest Metropolitan improvements London has ever known, and constitute a si monument of engineering skill. The gross cost of these the end of last year has been 2,500,887*l*.

In the v rtion of suburban London several engineering o considerable magnitude and importance

are now being carried on and are fast approaching completion. The first of these is the Chelsea Embankment, which was commenced in the autumn of 1871, and is expected to be completed by July next. The works commence at the western end of the Chelsea Hospital Gardens, forming, in fact, a continuation of the line of embankment which was constructed up to that point by the Commissioners of Woods and Forests. That scheme comprised an embankment and roadway between Vauxhall and Battersea Bridges, and the construction of a Suspension Bridge at Chelsea. The bridge was built and the embankment constructed a short distance beyond it, when funds failed and the works were stopped. The present embankment is being carried out by the Metropolitan Board of Works, from the point indicated to Battersea Bridge. The works consist of a river wall, having behind it a roadway 70 feet wide, flanked by ornamental grounds, a low-level sewer being carried about 30 feet below the roadway. The wall is formed of Portland cement concrete faced with granite, the surface of which, instead of being dressed smooth, as in the Victoria and Albert Embankment, is simply hammer-dressed, the style of masonry being that known as drafted and scabble-faced. The parapet and lamp pedestals are solid granite, fine dressed. The footings of the wall are only carried to a depth of 4 feet below low-water spring tides, the favourable character of the ground and the nature of the river traffic rendering it unnecessary to carry the foundations to a greater depth. The concrete backing of the wall is 12 feet thick at the base, 7 feet 9 inches midway of its height, and 4 feet 6 inches at the top, immediately under the footway of the embankment, and is benched or stepped out to the rear. The concrete is tipped into a trench formed behind the granite, and the water is let in upon it at the rise of the tide and pumped off at the fall, the work being proceeded with between tides. The work of construction is carried on from a timber staging laid with rails, while beneath it, and guided by the piles which carry it, are floating stages on which the concrete is mixed, and from which it is tipped into the trenches behind the granite. These floating stages form a novel feature in embankment construction, and were devised by Mr. Benjamin Cooke—one of our members, who is acting as engineer to the contractor, Mr. Webster. The work has made fair progress along its whole length, especially at the eastern end, where it was commenced. The completion of this work will open up an almost continuous river embankment and roadway, $4\frac{1}{2}$ miles in length, between Battersea Bridge and Blackfriars, the only break in the continuity being a quarter of a mile not embanked between Millbank and the Houses of Parliament.

The next Metropolitan improvement for notice is the Albert

Bridge at Chelsea, which crosses the river in a line with Oakley Street. It is being constructed upon the Ordish rigid suspension principle, in which the main girders carrying the roadway are suspended by straight inclined chains, which are maintained in their proper positions by being suspended by vertical rods, at intervals of 20 feet, from a curved steel wire cable. The bridge has a total length of 710 feet, and a width of 41 feet between the parapets, the roadway being 27 feet wide and the two footways 7 feet in width. The course of the roadway and the two pathways is uninterrupted throughout the whole length of the bridge, the towers being placed outside the parapet girders. There are three openings across the river, one of 400 feet in the centre, and one of 155 feet at each end. There is a clear headway of 21 feet at the centre of the bridge from the under side of the platform to Trinity high-water mark, while at the abutments the height is reduced to 10 feet. The towers carrying the main chains are four in number, placed in pairs, each pair being connected at a height of 60 feet above the roadway by an ornamental iron arch. Each of the towers is carried on a pier constructed of cast-iron cylinders sunk down to the London clay, and filled in with concrete. The foundations of the piers also consist of cast-iron cylinders, the bottom or cutting ring being 21 feet in diameter. The next ring above this tapers from 21 feet at its junction with the cutting ring to 15 feet at the top, from which point the piers are constructed with cylinders 15 feet in diameter up to the level at which the towers commence. The cutting rings are noteworthy as being the largest cylindrical castings ever made in one piece. The towers are of cast iron and of an ornamental character. The main girders are of wrought iron 8 feet deep, and form the parapets of the bridge, being continuous from end to end. The upper portions of the girders are perforated and covered with ornamental openwork castings. The roadway of the bridge is at a higher level than that of the embankment, so the footway of the latter is carried under the approach roadway of the former, while steps are provided by which foot passengers can gain the bridge roadway. The roadway of the embankment will be connected directly with that of the bridge by means of curved approaches laid with easy rising gradients, thus forming a very complete arrangement for communication both for foot passengers and carriage traffic. This work is being carried out under the supervision of Mr. F. W. Bryant, one of our past-presidents, who is engineer for the contractors.

Proceeding up the river, within two miles of the Albert Bridge are the works of the Wandsworth Bridge, which crosses the Thames close by the old Wandsworth pier. This bridge is designed to connect the districts of Wandsworth and Fulham,

and the want of such accommodation has long been felt. It is a lattice girder bridge, and is divided into five spans, one at each end of 113 feet 6 inches, and three in the stream 133 feet 4 inches each. The river piers are wrought-iron cylinders 7 feet 6 inches diameter, each sunk 14 feet into the London clay and filled in with concrete, a bed of concrete having been put in under them after they were sunk. There are two of these cylinders to each pier, connected together directly under the platform of the bridge. The abutment piers on either side of the river are of brickwork and masonry. At the centre of the bridge there will be a clear headway of 20 feet above Trinity high-water level, reduced to 14 feet at the abutments. The main girders are 12 feet deep, and are connected over the piers so as to be continuous throughout. The cross girders are placed 14 feet apart, and are riveted on the upper side of the bottom flanges of the main girders. The width between the main girders is 30 feet, of which 18 feet will be occupied by the roadway and 12 feet by two footways of 6 feet each. The approaches on the Surrey side consist of five brick arches of 20 feet span each, and another span of 20 feet carried by girders over a roadway. The approaches extend 280 feet beyond this, and are carried up in earthwork. On the Middlesex side there are 420 feet of embankment in the approaches, and a brick arch of 30 feet span, which adjoins the bridge. The works are progressing, and it is expected that the bridge will be opened in March or April next.

Such are the chief Metropolitan works now fast approaching completion. Considered in conjunction with the main drainage scheme, the new bridge at Blackfriars, the two embankments, the new meat market, and Queen Victoria Street, it will be seen that London has undergone within the last few years some most important changes, and has been the scene of some very great improvements.

The past year has seen the completion of two magnificent works of harbour construction, and the commencement of a third. The first—and certainly the finest—is the Portland Breakwater, which was opened by His Royal Highness the Prince of Wales in August last. The work of construction was commenced in 1849 from designs by the late Mr. Rendell, the resident engineer being Mr., now Sir, John Coode, who received the honour of knighthood on bringing the work to a successful issue. The breakwater commences with a pier which runs due east for about 1900 feet and terminates in a fort. Then comes an opening of 400 feet for the entrance of vessels from the southward, and on the other side the breakwater proper commences and is carried out to sea for a distance of 6000 feet, terminating in another fort. The pier consists of a

rubble mound, formed of stones of all sizes, from masses of several tons weight down to small fragments, with a wall of masonry constructed inside it. The sea wall is strengthened by counterforts 20 feet apart, and connected by arches carrying a platform or landing stage above them. The breakwater proper is a rubble bank formed of stones of all sizes as in the case of the pier. The total quantity of rough stone tipped into the sea was about 6,000,000 tons, the rate of deposit varying from 2000 to 3000 tons per day. The width of the structure at the base is 300 feet, and at the top 60 feet, the average height from the bottom being 70 feet. The sheltered area afforded by these works is about 2100 acres in extent up to low-water level, and the cost has been about 1,033,000*l.*

The second structure of this class which has been completed during the year is the pier and harbour at Douglas, in the Isle of Man. The work consists of two portions, an inner length or approach, and a pier proper. The approach is the continuation of a roadway on the shore, and extends 750 feet along a rocky ledge, when the pier commences, and is continued for a length of 400 feet, making the total length 1150 feet. The pier is 52 feet high from foundation to coping at the seaward end, and is laid throughout with a carriage way 30 feet wide, and two footways, each 10 feet wide. Along the pier, at intervals, are landing steps, and at its outer extremity is a cast-iron lighthouse. The distinguishing feature of this structure is that it is built entirely of ashlar work in concrete, blocks weighing from 5 to 10 tons each being used. The cost of the work was 46,400*l.*, and it absorbed 41,000 tons, or 675,000 cubic feet, of concrete. Besides the works I have described there is yet another now being carried out at the same place. This is a pier corresponding with that already referred to, and when it is completed the two will enclose an extensive sheltered water area. The second pier is being constructed in a similar manner to the first, some of the concrete blocks being in the foundations built *in situ* and weighing 220 tons each. The length of this pier will be 550 feet, but to complete the protection of the harbour it will have to be continued for about 450 feet more, at an angle with the present line of the work. The completion of the second portion of the work is expected in a few months' time. The engineer of these works is Sir John Coode.

The Harbour Works to which I have referred as having been inaugurated during the past year are at St. Heliers, Jersey. Sir John Coode is also the engineer here, and his design comprises a protecting breakwater, which will start from Port Elizabeth, pass by the Hermitage rock, and terminate with an elbow, the total length being 2700 feet. The outer portion will be about 60 feet high, and 38 feet in width at the top. There will also

reakwater about 900 feet in length between Fort Eliza-
d the shore. On the eastern side of the area to be
d the works will consist of a wall carrying a roadway
wide and 1400 feet long, at which point it will turn west-
by a curve 300 feet long, and will be extended for a distance
0 feet, terminating with an elbow 300 feet long, forming a
er and landing place, and having five low-water berths for
ers. A lighthouse will be placed at the end of the pier,
will have a total length from the mainland of 3400 feet.
works will be constructed in the same way as those at the
Man, and when completed will give a sheltered area of
es at high water ordinary spring tides. It is expected
he works of construction will extend over six or seven years,
hat the breakwater and landing stage will cost 253,000*l.*
ier will prove of great advantage to the steam vessels fre-
ng St. Heliers, which will be able to land and embark
gers alongside at dead low water of spring tides.

m harbours to ships is an easy and natural transition, so I
next touch upon the question of Channel communication.
d hardly tell you that for some years past propositions have
time to time been started for effecting a permanent com-
cation between our shores and those of France. These
mes have embraced tunnels beneath the Channel, through
wealden formation and through the super-imposed chalk
tion, tubular railways, both locomotive and pneumatic, on
d of the Channel, embankments through the Channel, and
dge over it. We have also had propositions for improving
harbourage on either side and starting a superior class of
ls in connection therewith. With regard to the latter pro-
ons they are by far the most sensible, involving as they do
utlay of only a few hundred thousand pounds, as against
expenditure of some twenty-five or thirty millions, and as
ring only two or three years for carrying them out, as
st a possible indefinite period. In connection with schemes
his latter class I have only to mention the names of Fowler
Hawkshaw, whose plans have been so well ventilated during
past two or three years as to need no further reference from
But there has been another class of propositions brought
minently forward during the past year, less costly, and to
mind more practical than any of the others. These propo-
ons recommended the taking of the harbour and pier accom-
dation as they are, and improving the Channel passage by the
tion of a class of commodious, quick-speed vessels of
draught, adapted to the existing harbourage on either
he first of these proposals, because the most practically
d at the present time—is that of one of our honorary
s, Mr. Henry Bessemer. The leading feature in

Mr. Bessemer's plans is the abolition of sea-sickness, one of the most prominent concomitants of Channel passages as at present performed. For several years past Mr. Bessemer has given very careful attention to this question, and has worked out several methods of preventing sea-sickness, each an improvement upon the last. Finally, he proposed to suspend a saloon upon a horizontal axis within the ship and in a line with her keel, and to control the rolling motion imparted to it by the vessel by means of hydraulic apparatus. The pitching motion he deals with by having a very long ship with low freeboard at either end, whilst her light draught would enable her to enter the waters of both English and French harbours at all states of the tide. To carry this proposition into effect there has been a vessel designed by Mr. E. J. Reed, C.B., 350 feet long, with 45 feet deck beam, and 65 feet over her paddle boxes, and which when fully loaded will draw but 7 feet 6 inches of water. The suspended saloon will be placed in the centre of the vessel, and the engines fore and aft, two pairs of paddles being used. The engines will be of 750 horse-power nominal, and the vessel is expected to attain a speed of 20 miles per hour. The saloon will be 70 feet in length, 30 feet in width, and 20 feet in height, and will carry on the top a promenade deck. This saloon will be governed by a set of powerful hydraulic apparatus connected with the under-side of the flooring, and so arranged that as the vessel rolls to either side the pressure or resistance afforded by the water is instantly brought into play and utilized in checking the motion. The apparatus is controlled by a pair of very sensitive equilibrium valves actuated by a hand lever. At this lever stands the attendant, who watches a spirit lever before him, and at the slightest variation of the bubble he at once suppresses the tendency of the saloon to follow the rolling motion of the ship. A vessel embodying all the features I have indicated is now being built, and will, when finished, be placed on the Channel service. That it will succeed there seems to be but little question, but if it should not the saloon could be fixed in a day or so at a very small expense, and the vessel could then be worked in the ordinary way, and would probably be the finest and steadiest ship ever placed on that station.

The next aspirant for the honour of annihilating sea-sickness is Mr. S. J. Mackie, a gentleman who has also devoted much time and attention to the subject. Mr. Mackie proposes a vessel 400 feet in length with 80 feet beam, entirely iron-built, and embodying an ingenious application of the tubular or box-girder system. The special feature in Mr. Mackie's vessel is the method of propulsion adopted, which consists in having two waterways or channels running from stem to stern of the ship in parallel courses, in each of which two paddle-wheels revolve.

These waterways are situated one on either side of the saloon, but within the hull of the vessel, and Mr. Mackie's theory is that the water is sucked in at one end and discharged at the other, upon the same principle as in the hydraulic mode of propulsion adopted in the 'Waterwitch.' The rolling motion is assumed to be provided against by the waterways, whilst the pitching is met by the great length of the ship. The engines are to be of 800 or 1000 horse-power, and are expected to give the vessel a speed of 20 miles an hour or more. Mr. Mackie has experimented with a steam-propelled model of large size, and from the results thus obtained he entertains the most sanguine hopes of success in a vessel of the dimensions I have stated.

The third system proposed is that of Captain Dicey, whose idea is borrowed from the rude contrivance of the native boatmen of the Indian Seas. In this proposition we have two longitudinal halves of a ship connected together at a distance of several feet from each other by means of cross girders, the paddles being placed in the channel between the two sections of the ship. However well this arrangement may overcome the difficulty of rolling, I have yet to learn that it meets the requirements of safety; or, considering the peculiar strains a ship has to encounter, that the arrangement is consistent with the first principles of engineering. One thing, however, seems pretty clear concerning the general question of international communication, and that is that at the present time some practical and vigorous attempts are being made to solve it, and thereby to render expeditious and comfortable one of the most tedious and comfortless passages known to modern travellers, a passage far more dreaded by some than a run across the Atlantic.

No incident of special engineering interest has occurred during the past year with respect to railways, although considerable activity has been manifested in minor matters connected with them. The first incident for notice is the opening on the 1st January of two new stations by the Midland Railway Company on the Tottenham and Hampstead line. These are the Junction Road and the Hornsey Road stations, the former being situated close to Tuffnell Park, and the latter being between the Upper Holloway and Crouch Hill stations. These stations will well meet the requirements of the populous and ever-increasing Metropolitan Northern Districts, and will give additional facilities to the suburban travelling public in general. Later on in the spring, the Great Eastern Railway Extension from Bethnal Green Junction to Stoke Newington was opened, and soon afterwards other extensions to the north of the Junction. All modern improvements were adopted in

the construction of the works, and in the new rolling stock which was provided for the traffic.

The London, Chatham, and Dover Railway have greatly improved their Crystal Palace route by the opening of their loop line at the Loughborough Road. Although the new Junction line is little more than a quarter mile in length it will effect a saving of no less than two miles between Ludgate Hill and the Crystal Palace, by cutting off the angle and circuitous route *viâ* Brixton. The new line, which is segmental in plan, is carried on forty brick arches besides three girder bridges.

In the provinces there was, first, the cutting of the first sod of the Hythe and Sandgate Branch of the South-Eastern Railway by Prince Arthur. The line branches off from the West Hanger Station of the South-Eastern Railway, whence it proceeds to Hythe, and thence to Sandgate, which will for the present form the terminal station, although there is a probability of an ultimate extension to Shorncliffe. The total length of the line is 3¼ miles, and its completion is expected about June next. There are no tunnels on the line, but some heavy cuttings occur at several points on the route.

In the early part of the year the Hayton, Prescot, and St. Helen's Branch of the London and North-Western Railway was opened. This branch forms the last link of a new direct route from Liverpool to Scotland.

About the same time the first sod was cut of a new railway which will connect the town of Presteign with the Leominster and Kington Branch of the Shrewsbury and Hereford Railway. The line is about 7 miles in length, and will supply railway accommodation to a district which has long felt the want of it.

Abroad, several railway matters have presented themselves for notice during the past year. On the morning of the 8th of January the mail for India arrived at Brindisi after having passed for the first time through the Mont Cenis Tunnel, taking for the journey twenty-four hours less than by the old route.

The close of January saw the first Sardinian Railway opened from Cagliari to Oristano. In the second section, which is to extend to Sassari, are many heavy works, high mountains and steep valleys abounding, so that its completion will be the work of considerable time, its rate of progress being very slow, at one point only 5 miles in three years.

The St. Gothard tunnel is proceeding slowly but surely, the boring being carried on by the aid of the new explosive compound, litho-fracteur. The nature and extent of the work may be inferred from the circumstance that the engineers estimate that they will require at least 1500 tons of this powerful explosive. It is interesting to notice that on the 15th of November last the first Japanese line of railway was inaugu-

rated. It connects Yeddo, the capital, with the port of Yokohama. This line, it is expected, will shortly be supplemented by a complete system of telegraphic communication.

A gigantic railway scheme has been proposed during the year for South Australia, involving the construction of a line from Port Augusta to Port Darwin, with branches towards Melbourne, Sydney, and Brisbane. The proposal originated with the South Australian Government, and the first cost is approximately estimated at 10,000,000*l*.

It is somewhat singular to read—as many of us of late may have read—of the progress of the Jaffa and Jerusalem Railway. We can hardly realize such modern innovations as these in a land to which such a peculiar and special interest is attached. But all must bow before the pioneer of civilization—the Railway—and thus we find that M. de Farey, the constructing engineer of the line I have alluded to, has started with a large staff of men to make this line. The railway is 75 kilometres in length, and is expected to be finished in about eighteen months. It will find a large traffic in the pilgrims to and from the sacred city, who are said to be looking forward to the accommodation it will afford them.

The Fairlie system of light railways and rolling stock has made some progress during the year in Russia and other parts abroad, especially in the United States, where it is being advantageously introduced. There can be no doubt of the efficiency of this system and of its value where judiciously applied.

From railways I almost instinctively turn to the consideration of tramways, and proceed to notice what has been done in this direction during the year. That has not been much, but the little that it is shows progress and indicates the success attending the introduction of this mode of conveyance when carried out on sound principles. The tramway system, introduced by Train, some ten years since, would have succeeded but for serious faults of construction.

The principal lines of tramways constructed during the past year are those in Edinburgh, Glasgow, Belfast, Dublin, Cardiff, and Birmingham. There have also been extensions of the London Street Tramway in the parish of St. Pancras, and of the North Metropolitan system in Shoreditch, Kingsland, Old Street Road, and to Finsbury Park. The Commercial Road branch of the same system has also been opened. It runs from the existing line at Whitechapel to the East India Docks. A new line of tramway has also been opened from Vauxhall Bridge through Kennington Oval to Camberwell Green. It is proposed to continue this line over Vauxhall Bridge to Pimlico.

Abroad, lines of tramway are being constructed in Bucharest,

Lisbon, Calcutta, and Paris. The Lisbon tramways are of considerable length, one line of 17 miles running from Lisbon to Cintra, and another of 60 miles from Lisbon to Torres Vedras. They are to be steam-worked, engines and cars of special construction being used. The tramway consists of two outer longitudinal timber ways and a central iron rail. The driving wheels of the engine are outside and run upon the timbers, the central wheels being double flanged and acting as guides. In the carriages the central wheels are the carriers, those outside acting as guides to preserve the balance of the carriage, which somewhat resembles a bicycle. A locomotive and some of the rolling stock have lately been tried in England with very satisfactory results.

The most important event of the past year in connection with electric telegraphy was undoubtedly the completion of the Australian telegraphs. The establishment of telegraphic communication between Great Britain and Australia has long been contemplated and desired, and by the accomplishment of the fact, one more instance of spirit and energy, combined with indomitable perseverance, has been added to the long list of which telegraphic science can boast. The following are the details of the telegraphic route from Falmouth to Port Augusta:

	Miles
Falmouth to Gibraltar *viâ* Lisbon (Cable)	1,250
Gibraltar to Malta (Cable)	981
Malta to Alexandria (Cable)	819
Alexandria to Suez (Overland line)	224
Suez to Aden (Cable)	1,308
Aden to Bombay	1,664
Bombay to Madras (Overland)	600
Madras to Penang (Cable)	1,213
Penang to Singapore (Cable)	301
Singapore to Batavia (Cable)	560
Batavia to Bangoewangi (Wire)	480
Bangoewangi to Port Darwin (Cable)	970
Port Darwin to Port Augusta (Wire)	1,800
Port Augusta to Adelaide	212
Total	12,382
Lisbon to Falmouth	268
Total	12,650

In Queensland it is proposed to devote 60,000*l.* to the purposes of telegraphic extension. It is expected that Brazil will be connected by telegraph with Portugal before the close of 1874. The Baron de Mauá, who has done so much for South America, is moving in the matter. The extension of the telegraph from Graham's Town to Coromandel in New Zealand is nearly completed.

Telegraphy progresses in Russia, the second section of the telegraph line to Turkestan having been opened in September last from Semipolatinsk to Surginpol.

The manufacture of the duplicate French Atlantic and Great Western Cables is steadily progressing.

The Spanish Government has granted a concession for a direct cable between Barcelona and Italy, and another concession has also been granted for a cable between Barcelona and Egypt.

These jottings indicate a generally active condition of telegraphic science, a science the limits of which were not very long since circumscribed by the walls of a lecture-room, but which in its practical application has overspread the face of the whole earth.

For some years past I have held the opinion that the science of Pneumatics, practically applied, is destined to subserve many important purposes in connection with engineering. Every year almost finds this opinion confirmed in one way or other by the actual tests of practice. During the past year two applications of the principle have been successfully worked out, whilst in other cases progress has been made. The first application I would notice is that to the purposes of signalling, which has been perfected by Messrs. Homfray and Co. It may be within the knowledge of many present that some five years since Mr. Wier brought out a system of signalling on the pneumatic principle. The apparatus worked exceedingly well for a time, but owing to defects in the constructive details which gradually developed themselves the system proved unsuccessful. By introducing a cast-iron cylinder in place of German silver, corrugated chambers for the retention of the air under pressure, and by modifying the supply valves, Messrs. Homfray have rendered the pneumatic system of signalling a success. The apparatus consists of two instruments, a communicator and an indicator, connected, at any required distance apart, by means of a number of small metal tubes, each communicating with a written signal covered by a hinged shutter in the indicator, but uncovered in the communicator. A lever on the latter instrument moved and notched up under the signal required to be made causes a bell to ring at the indicator end, uncovers the corresponding signal, the shutter remaining open until the lever is moved from the notch. This system is being applied for steering and engine-room signalling on board ship, and as far as can be judged at present it is one of the most simple and effective means of signalling we have.

The second application of the pneumatic principle is a very special one. It has been utilized by Messrs. A. Ransome and Co., for the purpose of clearing sawdust and shavings away from

wood-working machinery. Hoods are placed over, or funnel-shaped receivers under, the various machines, and these contrivances being connected with tubes in which a strong exhaust is produced by means of a fan, the shavings or sawdust are drawn off from the machines to the fan, beyond which point they are forced under pressure to any convenient spot that may be desired. The first example of this unique and successful method of dealing with the waste of a workshop is to be found at the factory of Messrs. Peto Brothers, at Pimlico.

A matter for notice in connection with the present subject, as indicating progress in the application of the pneumatic principle, is the completion, during the past year, of the Pneumatic Dispatch Company's tube between their station in Holborn and the General Post Office. This opens up a route between the London and North-Western Railway at Euston Square and the Post Office, and although this means of transit for parcels and mail bags, &c., has been proved to be reliable, rapid, and cheap, neither the Railway Company nor the Post Office authorities have as yet availed themselves of its services. The Post Office authorities, however, have been far wiser in another instance. They have adopted a system of pneumatic dispatch in their telegraphic department, which, although not a novelty of the past year, is highly interesting in itself. The tubes here are of small diameter, and so arranged that while the carriers working in them are of corresponding small dimensions, and consequently require as great power to propel them, their smallness is compensated for by the rapidity with which they are dispatched between the stations. These piston carriers fit the tubes exactly, so that no loss of propelling power arises from leakage of air past them. The tubes have no terminal points, but each forms a closed pneumatic circuit communicating at a central point with an air pump. The air thus travels round and round in the circuit continually in the same direction, so that on introducing a carrier containing telegrams into the tube at the pumping-station, it would, if not intercepted at an intermediate point, travel completely round the circuit, eventually arriving at the pumping-station whence it started. But this, of course, is not the case, as there are several stations on each circuit at which carriers are both received and dispatched. For this purpose a couple of chambers, about 18 inches long, and of the same diameter as the tube, are used, being arranged so as to break and restore the continuity of the tube very quickly. Into one of these chambers the carrier is inserted, and the act of removing the second piece from the tube brings up the first in line with the tube, and the carrier with its charge of messages is rapidly started on its journey. By means of a movable stop the incoming carriers are prevented from passing the station for

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, and this the working man is, unfortu-

nately, but too apt to do. He knows that labour is valuable, and that knowledge is to him a power whereof he avails himself, showing little or no consideration for relative interests. Nothing will satisfy him but a high advance of wages, he being perfectly oblivious to the fact that any advance can bring with it but limited advantages. Strikes are infectious, and extend very rapidly from one department to another. The result is that the labourer finds to his cost, that although he may obtain an increased rate of pay he is not one whit the better off, inasmuch as his slight gain is probably more than absorbed by the increased cost of the commodities he requires. Beyond this there is the fact that labour has assumed a position of independence, not originally its own, at a most trying period—that of active trade. In view of this the obligations of capital will probably not be found to extend to the avoidance of short time and the reduction of wages when profits are low. In other words, the attitude of the labourer in the past has so altered the relations of master and servant as to render it impossible that relative interests can be adjusted otherwise than upon principle, instead of being regulated by feeling, as formerly they were. The matter is one which has an important bearing upon the future.

The question of the rise in the price of coal is one which has pressed heavily upon all during the past year. It still so presses, although there can be but little doubt that as the means of production have been improved by increased mechanical application, the influences which have operated to advance the price of coal will ultimately be neutralized.

Whilst on the subject of minerals it may be interesting to note that 1872 was the first year in which phosphate of alumina has been imported from Canada and the States, about 25,000 tons having already been received from that quarter. As this is a chemical fertilizer of great value it is fast growing into favour, and it will doubtless form a very large and important item of commerce in the future.

I recalled at the outset the memory and services of some of our deceased fellow-workers; upon us, their successors, devolves the duty of bearing each a part in promoting the great scheme of material progress. Let us remember, then, that the least part, honourably performed, is equal to the greatest, and let us endeavour so to shape our ends that our private interests may not outweigh those of our profession, nor obscure those which each one of us ought to feel in the "Society of Engineers."

N THE CHAIR.

BRAKES.

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7. That the retarding force be applied throughout the whole train instantaneously, and be capable of being increased or diminished at the will of the driver or guard.

8. That it is necessary that the brake allow of any portion of the train being slipped.

9. That the coupling of carriages indiscriminately shall in no way affect the working of the brake.

10. That the brake shall be devoid of complicated parts, or any attachments that would easily get out of order or require extreme care on the part of railway servants.

11. That the application of the brake blocks shall not be attended with pressure on one side of the wheel and axle only, and so tend to uneven wear.

12. That the pressure on all the wheels of a carriage shall be the same, and as an additional precaution against vibration, the brake blocks shall cushion on air, metallic springs, rubber, or some other material of an elastic nature.

13. That the brake apparatus be in no way liable to get out of order by sudden atmospheric changes.

The conclusions at which the author arrived were:—that every engine and carriage should be fitted with brake apparatus capable of reducing them from a speed of 60 miles per hour to a state of rest in a distance not exceeding 220 yards on the level in ordinary weather; that a retarding force of 18 per cent. of the weight of the train was sufficient to do this; that cast iron was generally more suitable than wood as a material for brake blocks; and that experiment pointed out that a pressure of $2\frac{1}{2}$ tons was required to be applied to the cast-iron blocks fitted to each of the four wheels of a carriage weighing 10 tons, and 1·80 ton if wooden blocks be used in like manner.

The author would here remark that the descriptions in his preceding paper followed one another according to the length of time the respective brakes have been on trial in this country; and therefore as he proposes to adopt the same rule in the present case, the next one for notice is the atmospheric brake.

This brake is commonly known as the Westinghouse air brake, being named after the inventor, Mr. Westinghouse, of Pittsburgh, United States. It has been introduced practically into this country about ten months, and fitted to trains on the Caledonian, London and North-Western, Metropolitan District, and the London, Chatham, and Dover Railways; and according to reliable information appears to be giving satisfaction. That this would be the case is no more than might reasonably have been anticipated, owing to the fact that this brake has been working successfully for a period of nearly four years in the United States of America, and is there fitted, it is believed, to

motives and 5000 cars, running on about 100
of railway, including the whole of those of the
Company. From its extensive use then on the
the Atlantic it must be admitted to be one pos-
durable merit, and therefore deserving the careful
those civil and locomotive engineers entrusted with
tion and supervision of railways in this country.
mence of description the author proposes to consider,
ngement for the compression and storage of the air,
; and secondly, its distribution as a retarding force
tion of a train weighing 150 tons, made up of engine
weighing 50 tons, and ten carriages weighing 10 tons
done when describing the hydraulic and chain brakes.
1, 2, 3, and 4, Plate 1, show the brake apparatus:
epresents elevations and plan of a portion of engine,
nd one carriage; the air pump and reservoir fixed to
; the brake cylinders and other apparatus fitted to the
and carriages. Fig. 2 represents a section through the
and air cylinders. Fig. 3, plan and section of steam
der and section taken between it and air cylinder, the latter
wing the arrangement of packing used for the rod connecting
pistons. Fig. 4 represents longitudinal and transverse sec-
ons of brake cylinder, and the coupling for connecting the
exible pipes between the carriages.

The steam cylinder A, in conjunction with the air cylinder B, is fixed to the side of the locomotive as shown, and is 6 inches diameter and 10 inches stroke. The admission and emission of the steam is controlled by the motion of the conical valves contained in the valve case C, which are cast in one with the stem C^1 passing out through the top of the cylinder. This stem is fitted with an arm D, one end of which carries a stud working in a transverse slot made in the end of the piston rod of the small steam cylinder E (shown in Fig. 2). The piston rod of the cylinders A and B is hollow for a portion of its length, so as to admit a rod F, having a collar at each end which is struck by the clip plate shown on the upper side of the piston. The movement of the rod thus occasioned opens and closes the valve G, so as to admit steam alternately into each end of the cylinder E, thus giving through its piston rod and the arm D the required motion to the rocking valves contained in the case C. A pipe *a* supplies steam from the boiler to the cylinder A, and a pipe a^1 leads the exhaust steam to the chimney. Set screws are provided (as shown in Fig. 2) at the per and lower ends of the valve stem C^1, so that the valves be easily adjusted. The exhaust ports of the cylinder E so placed that a small quantity of steam is left in the

cylinder at the end of each stroke, which forms a cushion and prevents noise.

It will be noticed that the piston rod connecting the two pistons is square on plan, this form being adopted as a safeguard against the pistons turning during the stroke, and is found, with the effective method of packing introduced between the cylinders, to answer its purpose in a satisfactory manner. The packing is of hemp, kept in its place by glands, which can be readily tightened by means of the bolts shown. The holes in the cylinder covers through which the rod passes are bored cylindrical, but contain recesses into which Babbit metal is run so as to fit the piston rod. The air cylinder B is of the same diameter as the steam cylinder, and supplied with air through the strainer *b*. The section valves b^1 and delivery valves b^2 are ordinary conical valves seated in the air passages leading to the upper and lower ports and discharge pipe C, connected with the reservoir. It will be observed in Fig. 2 that provision is made for drawing lubricating oil into the cylinder with the ingoing air, and it should be mentioned that mineral oil is found most suitable, as obviating any difficulty experienced with animal and vegetable oils, on account of their carbonizing when submitted to the high pressure induced while compressing the air in the reservoir.

The author has on several occasions seen this pump forcing air into the reservoir against a pressure of 60 lbs. on the square inch, at speeds varying from 10 to 60 strokes per minute, with the most perfect regularity, and thinks that from its exceeding compactness and steady working it must be allowed to answer the purpose for which it is designed in a most satisfactory manner. By means of the pipe *c* the air is conveyed to a wrought-iron reservoir, H, fixed under the engine, and having a capacity of from 12 to 15 cubic feet. This reservoir is provided with a safety valve, which is generally set so as to limit the pressure of air from 60 to 70 lbs. on the square inch. To allow for any slight leakage that may take place through this valve or any other portion of the brake apparatus, and also to compensate for the lowering of the pressure due to the loss of heat by radiation from the shell of the reservoir, the pump is kept continually running at a very slow speed until the brakes are applied, when the pressure in the reservoir being reduced, and the resistance therefore to the motion of the pistons reduced also, their speed, automatically, at once becomes accelerated accordingly, but again decreasing until the normal pressure in the reservoir is attained.

We now come to the arrangements provided for the distribution of the air stored in the reservoir, throughout the train as

motion. From the reservoir H, just
ls to the three-way cock J^1, placed within
e driver. A branch of this cock is open
hile the other continues the pipe J to a
r cock, J^2, placed under the tender, and
r branches to the duplicate pipes H^1, H^2,
¾-inch gas-tubes running throughout the
ge, and continued between them by means
joined by the ingenious couplings K
hese couplings are made to a uniform gauge,
hat the parts correspond, whichever end of
nted. The coupling consists of male and
On the latter is fixed, by means of a clamp,
which are bent at one end so as to lap over a
ast on *k*, and hold the two parts sufficiently
withstand the strain put upon them by the
nd also to yield and allow the couplings to
f any part of the train breaking away. To
the coupling, notches are made in the ring *k*,
on that a twist must be given to one of the
tubing before the springs can be inserted, by
y tendency to accidental separation is avoided,
the tubing to its natural position. The male
s of the coupling are fitted with a valve, the
abut one on another when the joint is made and
ves open, thus ensuring a free passage for the air
whole length of the train. If the parts become
by any means the valves fall into their seat and
air-tight when the brakes are applied by the
ir in the pipe. As a further security against
diarubber ring is inserted in a recess in the
art *k*, and under it is a small air space communi-
s with the interior of the coupling, so that the
in the pipes tends to expand the rubber ring and
inst the interior surface of the female part k^1,
packing which resembles in its ingenuity the
hat made the hydraulic press a success.

the air pressure to stop the train, a cylinder 8″
12″ stroke is fixed to the under side of the framing
nd each carriage, these cylinders being connected
ues of air pipes H^1, H^2, by means of the branch
alves M. The pistons of the cylinders L are
cupped leather, containing a metal spring, l^1,
to prevent the leather shrinking from the
he cylinder. The piston rod passes through
n the cover of the cylinder, into a sleeve or

mouth-piece, l^2, into which the thrust rod l^3 enters and abuts against it. By the adoption of this mode of connection the brakes are left quite free for application by the ordinary hand appliances if necessary. The cover of the opposite end of the cylinder to that through which the air from the pipe enters is provided with a quarter bend-pipe to allow the atmosphere to escape when the piston is being pushed forward to apply the brakes and to admit it while the brake blocks are being released. The valve M may be described as an equilibrium valve, its construction being such as to admit air from the pipes H^1, H^2, into the cylinder L simultaneously, but if from accident or other cause one of these pipes becomes defective, the driver may, by turning the three-way cock J^2 under the tender, isolate it, and at the same time, as will be readily understood from the engraving, cause the valve M when the brakes are applied to close itself with considerable force on the india-rubber seating provided, and so render the escape of air to the defective pipe almost impossible.

We now come to the arrangement of gear by which the blocks are forced on the wheels; it should, however, be first mentioned that the engravings show the one generally adopted for carriages not previously fitted with brake apparatus, as being the most simple and efficient. Where, however, any other description of brake is in use, the brake cylinders, &c., are adapted accordingly, and the ease with which this can generally be done, as in the case of a train on the London and North-Western Railway, is, in the author's opinion, of sufficient importance to deserve being mentioned as a speciality of Mr. Westinghouse's invention. The arrangement of gear referred to is designed to equalize the pressure exerted on each block, however unequally they may wear. To attain this the brake shaft is made in two parts, the outer end of each being supported by a link hung from the framing of the carriage, while the inner ends are carried by a cast-iron bracket also fastened to the framing, sufficient play being allowed in the boss, so that the outer ends of the shafts may swing far enough to take up the maximum wear of the blocks. Each shaft has an arm fixed near its inner end, their extremities being connected by a link, to the centre of which is fastened the thrust rod abutting at one end against the piston rod of the cylinder. Near the links carrying the brake shafts, and in line with the wheels of the carriage, are fixed the double-headed levers, to which again are fastened the thrust rods connecting the cast-iron blocks, as shown in the engraving. These blocks, it should be mentioned, are self-adjusting, so as to always exactly fit the tires, however much the carriage springs may be affected by

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e to the mitted to	= about 2½ cub. feet.
ervoir to lers, and	11 to 13, 50.
reservoir being ad- om.. ..	60 to 40 lbs. per square inch.
e pump to the reser- ch, was ..	1½ minute.
10 lbs. per equired to	9 single strokes.

The number of strokes to keep up 60 lbs. per square inch in the reservoir is not given in this instance, as exception was taken at the time of the safety valve blowing off at that pressure. If now we accept the law that the pressure of an elastic fluid maintained at a constant temperature is proportional to its density, we have decrease of pressure from 60 lbs. due to expansion of air from reservoir into the cylinders $= \frac{60 \times 11}{13 \cdot 50} = 49$ lbs. per square inch, as compared with 40 lbs. the actual pressure obtained, thus showing leakage to some extent. It will perhaps be noticed that no consideration has been given to the variation of pressure due to the alteration of the temperature of the air during its expansion in the cylinders and pipes. With reference to this the author would merely state that he thinks the temperature of the compressed air in the reservoir may be taken as being practically the same as that of the atmosphere; the heat due to the compression being lost by radiation from the large surface exposed by the shell of the reservoir. Therefore any loss of temperature owing to the slight expansion of the air that takes place when the brakes are applied, is at least fully compensated for by the increased speed of the pump, and the rapid absorption of heat due to a large surface exposed by the pipes and cylinders. Any calculations embracing this consideration would only tend then to complicate the subject without giving a corresponding advantage.

The next series of notes were made on the 12th of last month, while making an experimental trip with a train, of engine and eight carriages fitted with this brake, running on the Metropolitan District Railway between the Mansion House and West Brompton stations:

1. Length of reservoir = 6·75 feet.
   Diameter of reservoir = 1·60 foot.
2. Capacity of reservoir = 13·50 cubic feet.
3. Diameter of cylinders under carriages = 8 inches area of pistons to ditto = 50 square inches.
4. Length of stroke made by piston rod to apply the brakes.

No. 1.	Cylinder	5·00	inches.	No. 5.	Cylinder	4·00	inches.
„ 2.	„	5·50	„	„ 6.	„	3·50	„
„ 3.	„	5·75	„	„ 7.	„	4·00	„
„ 4.	„	6·25	„	„ 8.	„	4·50	„

Average length of stroke made by each piston $= \frac{38 \cdot 50}{8} =$ 4·80 inches.

Stroke of air-brake cylinder to engine 10 inches and cubical capacity = 600 cubic inches.

5. The expansion of the air therefore due to the stroke of the pistons, pipes, &c.	= 2·30 cubic feet.
6. The ratio of capacity of reservoir to capacity of reservoir plus that due to the pipes and stroke of pistons	13·50 : 15·80.
7. It was observed that air in the reservoir was reduced in pressure, when the brakes were applied, from	60 lbs. to 47·50 lbs. 47·50 lbs. to 40 lbs. 40 lbs. to 33·50 lbs.
8. That the time required by the pump to raise the pressure from 35 lbs. to 60 lbs. (with 110 lbs. of steam only)	2 minutes.
9. That the number of single strokes required to keep the pressure at 60 lbs. per square inch, was ..	3 per minute.
10. That the number of single strokes required to keep the pressure at 40 lbs. per square inch when the brakes are applied	6 per minute.

11. 110 lbs. of steam-raised pressure from zero to 60 lbs. in 3 minutes, the gauge registering 35 lbs. pressure at the end of 1 minute and after 105 single strokes had been made.

12. 110 lbs. of steam-raised pressure in reservoir from 35 lbs. to 50 lbs., with 70 single strokes in 1 minute.

If we now measure the reductions of pressure recorded in Note 7 by the law of expansion for elastic fluids we shall have

1st. $\frac{60 \times 13{\cdot}50}{15{\cdot}80} = 51{\cdot}25$ lbs. instead of 47·50 lbs. as stated.

2nd. $\frac{47{\cdot}50 \times 13{\cdot}50}{15{\cdot}80} = 40{\cdot}60$ lbs. instead of 40 lbs.

3rd. $\frac{40 \times 13{\cdot}50}{15{\cdot}80} = 34{\cdot}20$ lbs. instead of 33·50 lbs.

We have here then an illustration which shows that the ingenious couplings and other apparatus fitted to the carriages act with remarkable efficiency, at least so far as preventing loss of power from leakage. The trial trip referred to above was made under the ordinary conditions of traffic, *i. e.* stops were made at each station, and so far as the author could judge, in distances varying from one-half to two-thirds of the length of the train, but, it should be stated, without that jerking and vibration so frequently experienced on this line. The pressure in the reservoir recorded by the gauge on starting from the Mansion House Station was 58 lbs. on the square inch, and that indicated

[illegible] lbs.
[illegible] was
[illegible] quick

[illegible] of re-
[illegible] motion of
[illegible] tons each, and
[illegible] doing so, how-
[illegible] the data he starts
[illegible] average coefficient
[illegible] blocks, and ·18
[illegible] it
[illegible] ing
[illegible] may be
[illegible] 220 yards [illegible]
[illegible] pressure of 7·20 tons to
[illegible] made of cast iron and

[illegible], the cubical
[illegible] is taken at
[illegible] under the
[illegible] their
[illegible] they
[illegible] the
[illegible] ks
[illegible] ve
[illegible] cylinder =

[illegible] × 10 = 4000
[illegible] × 30 / 100 = 2000
[illegible] for pipes = 1820

[illegible] cubic inches 7820.

[illegible] H will be as 13·50
[illegible] law of expansion the
[illegible] 60 × 3 / 4 = 45 lbs. on

[illegible] the working of the
[illegible] Western and Metro-
[illegible] this theoretical
[illegible] on the square inch.
[illegible] ure for the brake's

efficiency, because the retarding force is applied to each in proportion to its weight, we have:

Area of cylinder piston = $8^2 \times \cdot 7854 = 50$ inches.

Pressure on piston therefore = $50 \times 40 = 2000$ lbs.

Pressure on blocks then due to leverage = $2000 \times 8 =$ 16,000 lbs., or say 7·20 tons.

Now 7·20 tons is the maximum total pressure to be applied to the wheels of a carriage if wood blocks are used; it is also sufficient for cast-iron blocks in wet and foggy weather, when the brakes are most needed, but in ordinary weather with ·20 as the coefficient of friction, the distance moved by the train after the blocks had gripped the wheels would be as

$$9 : 7 \cdot 20 :: 220 : 283 \text{ yards.}$$

Although it has been stated that this brake is capable of exerting all the useful amount of force to stop a train made up of engine, tender, and ten carriages as described in the least possible distance; yet we must not overlook the fact that for every additional carriage emergency may require coupled to the train, to meet the demands of exceptional traffic, the comparative power at the command of the driver to reduce the speed of the train would be lowered accordingly, owing not only to the pressure of the air on the pistons being reduced by the further expansion it would have to undergo to supply the cylinders of the extra carriages, but also to the additional time required by the air to travel such increase of distance before the blocks would bite the wheels with the full force available. On the other hand, however, it must be remembered that the requirements of the public are best met by running short and frequent trains, rather than long ones at considerable intervals of time. If this, and the comparatively slow speed of long trains be considered, and also the increase of pressure which may be attained in the reservoir if necessary, we may certainly describe this brake as one possessing sufficient power, under the conditions mentioned, for a train of reasonable length.

To show this the author introduces the following calculation:

Suppose five additional carriages be attached to the train and the brake blocks to be worn their maximum distance as before; but the air pressure in the reservoir be raised to 70 lbs. on the square inch instead of 60 lbs. In this case we should have additional quantity of air required for cylinders $= 400 \times 5 =$ 2000 cubic inches, which, with quantity required for pipes, would make, say, $1\frac{1}{2}$ cubic foot. The ratio of expansion then would be as $13 \cdot 50 : 13 \cdot 50 + 4 \cdot 50 + 1 \cdot 50$, or as $9 \cdot 00 : 13 \cdot 00$.

$$\therefore \text{Reduction of pressure due to expansion} = \frac{70 \times 9}{13} = 48 \cdot 50 \text{ lbs.}$$

as compared with the pressure of 45 lbs. as obtained before; thus showing the efficiency of the brake with a train of fifteen carriages, and assuming the whole of the brake blocks to be the great distance of 1 inch from the tires. The author is therefore of opinion that if the cast-iron blocks were never allowed to exceed a distance of $\frac{5}{8}$ths of an inch from the tires, this brake would be capable of affording the maximum amount of retarding force to meet any emergency exceptional traffic would require.

The liability of the pump and other apparatus to get out of order and so reduce the efficiency of the brake, can only be obtained by a more extended experience. All machinery, however, is more or less liable to accident, and the inventor, who appears to have neglected no details, has met this to some extent by the simple arrangement shown, which enables the tender brake to be worked by hand in the usual manner. The hand brake may also be applied to the guard's van at the trail end of the train, an arrangement the author considers—in this case—absolutely necessary.

Another question inviting discussion is the cost of working the pump apparatus, as in the case of the brakes already described, the motion of the train is made to retard itself. On this point the author considers, from observations he has made, that for a train as referred to above the amount of steam consumed for ordinary stops would be about 12 cubic feet. If we now take such an extreme case as would be met with on the Metropolitan District Railway, between the Mansion House and West Brompton stations, where the stops during the day number about 350, we should have a consumption of steam equal to about 4200 cubic feet, to which would have to be added the quantity used while the pump was slowly working between the stops, thus making a total of about 5000 cubic feet of steam; on the cost of producing which I hope our past President, Mr. Adams, will give us the benefit of his opinion.

A system of signalling is combined with this brake, which appears well worthy of careful attention. No attempt, however, is made to describe this apparatus, as the author considers that by so doing he would be exceeding the limits of his subject.

To complete his description of the brake the author has only to point out how far it complies with the conditions laid down in his previous paper.

1. The engine driver applies the brakes: this condition is complied with with great simplicity.

2. A train of reasonable length moving at a velocity of 60 miles per hour may be brought to a state of rest by this brake in ordinary weather, and by a retarding force applied from the

engine, in the least possible distance from the time the brake blocks press the wheels with the full force available.

3. This condition is not complied with as the brakes cannot, with the present arrangement, be applied from the trail end of the train, as well as from the engine, neither will the brake act automatically in the case of any portion of the train breaking away.

4. This condition is fully complied with.

5. No exertion is required to apply the brakes: this condition is fulfilled in the most perfect manner.

6. The air pipes being in duplicate, this condition is practically complied with.

7. This condition requires the pressure on the blocks to be instantaneous. To ascertain how near this brake meets this requirement is a problem involving many difficulties. The author, however, has given considerable attention to the question, and has found that the average total loss of time due to the air having to expand itself throughout the whole length of the train was about two seconds. Not satisfied, however, as to the correctness of his conclusion, he submitted a few days ago the problem to Mr. G. Wilson, a gentleman well known through the columns of 'Engineering' for the elaborate investigations he has made on the efflux of air. After kindly giving the matter careful consideration, Mr. Wilson advised the author to rely upon experiment alone, at the same time stating his willingness to kindly assist him in the matter. In face of this recommendation the author, in justice to the various inventors, sees no alternative but to submit to so eminent an authority. If therefore the inventor will kindly give his sanction to such experiments being made, the author will gladly undertake to carry them out. As the driver can regulate the pressure applied, the remainder of this condition is therefore complied with.

8. The excellent arrangement of coupling between the carriages may render this condition capable of being complied with; there is, however, some reason to think that considerable strain would be thrown on the flexible tubing, sufficient perhaps to cause its fracture.

9. The ends of the carriages may be brought together indiscriminately, as each end is fitted with a male and female part, so that whichever way the carriages are turned the opposed couplings fit each other.

10. The whole of the apparatus may be considered as devoid of complicated parts.

11. This condition is not complied with, as the brake blocks are applied to one side of the wheels only, and therefore tend to produce uneven wear.

12. The pressure put on all the wheels of a carriage by the

arrangement shown is the same, and by the cushion of air in the brake cylinder precaution is ensured against undue vibration.

13. The brake apparatus is not liable to get out of order from atmospheric change.

From the above observations it is seen that the atmospheric brake complies, with but one or two exceptions, with the whole of the conditions that are considered necessary to be fulfilled by a perfect continuous brake. It is therefore one deserving special attention from those authorities who have the safety of the travelling public in their keeping.

Our cousins on the other side of the Atlantic seem determined to outstrip us in devising the best means for ensuring as far as possible the safety of railway travellers by efficient brake power; for we find the next brake most deserving attention to be one invented by Joseph Olmstead, of Chicago, Illinois, United States of America, and known as the electro-magnetic brake.

This brake is now being introduced into England by General Chapin, of the United States, from whom it has received several improvements in its details, and such modifications as have been necessary to render it more suitable for English rolling stock. Chapin's electric brake—that being the name it is known by in this country—has been fitted to five out of a train of ten carriages which have been running for the past three months on the North London Railway between the Broad Street and Blackwall stations. As it is very essential for all that an invention likely to be of so great a service to the public as an efficient railway brake, should while on probation be subject to as great a test of its general efficiency as possible, the author cannot but congratulate the inventor on having succeeded in obtaining a trial of its merits on the line above mentioned, because the wear and tear it will be subject to there could only have been equalled in this country by the Metropolitan and the Metropolitan District Railways; so that we may conclude that if it stands the test of durability on that line, it is capable of meeting the requirements of ordinary traffic, at least so far as moderate train speeds are concerned. It is not difficult to understand the many advantages that this kind of brake must possess if it can be applied, so far as the mechanical arrangements are concerned, in a simple and effective manner, owing to the ease with which powerful forces can be generated by electro-magnetism, and made to act at considerable distances from their source.

In describing the brake apparatus the author proposes, after referring to the drawings, to deal first, with the battery and keyboard; secondly, the conductors and magnetic clutch; thirdly, the arrangement for applying the blocks to the wheels. Fig. 5 shows the battery in the guard's van, the arrangement

of conductors, magnetic clutch, &c., and the local battery fitted to each carriage; Fig. 6 is the magnetic clutch; Fig. 7, the keyboard now in use. Fig. 8 shows section of keyboard and view of coupling. Fig. 9 illustrates the automatic arrangement for applying the local battery in case the train breaks away at any part. Fig. 10 shows proposed arrangements for applying cast-iron brake blocks to each side of the wheels.

The battery A is fixed in the guard's van at each end of the train, and is of the kind generally known as Highton's, which is one composed of zinc and carbon, the former being diluted with a strong solution of salt and the latter with a weak solution of a mixture of sulphuric and nitric acids, and contained respectively in a glass cell 6 inches diameter, and a porous cell 4 inches diameter, each being about 8 inches deep. This combination gives, as is well known, not only a very powerful battery, but also one in which the substances used can be procured at comparatively little cost. Each battery, as fitted to the train on the North London Railway, is formed of sixteen cells, one being reckoned for the main wires and three for each of the five carriages. Copper conductors lead to the keyboard, giving battery tension equal to eight, twelve, or sixteen cells, the intention being to give to the guard not only the means of applying the brakes with a force he may vary as circumstances may require, but also to compensate to some extent for the gradual loss of power that takes place during the time the battery is kept in operation. As soon as the magnetic force becomes insufficient—which is found to be about once a fortnight—the battery requires the operation of cleaning and re-silvering the zinc plates, and an addition of the solutions above named, when it is again ready for use, thus involving a cost but little more than that due to the labour incurred. We next come to the keyboard, which is also fixed in the guard's van at each end of the train; but, as will readily be understood, may also be fitted in any convenient position on the engine, so as to be within command of the driver. It is constructed of wood about 18 inches long and 12 inches wide, and fitted with the brass plates B, C, D, E, F, G, H, and J, and the key K. At the back of K are two contact springs L, M, the former being connected at its lower end to the key, while its upper extremity carries a brass contact faced with silver, bearing on the plate B in such position that when the key is moved from the off to the on side of the board it will touch in its passage the centres of the plates C, E; the latter contact spring M, which is insulated from the key by means of ebonite, is fitted with similar contacts at each extremity, so as to touch the plates D, F, G, H, and J, when moved over, as just described.

The zinc and carbon wires are brought from the terminals of

the battery to the back of the plates C, D, respectively, the former being also connected to the plate H and the latter to the plate E. Conductors are also brought from eight and twelve cells of the battery to the plates F and G respectively; while a main wire connected to the plate J passes to the magnets under each carriage, and thence to the similar plate on the keyboard at the opposite end of the train. A second main wire, which brings the galvanometers within the circuit, returns direct under the carriages and connects the current with the pins carrying the key K in each van. It will be noticed that the brass guide for the key is marked R, 1st, 2nd, 3rd, which denote reversed current, eight, twelve, and sixteen cells of battery power respectively. To explain the action of the keyboard in applying the brakes, let us distinguish the similar contact plates and key at the opposite end of the train as B^1, E^1, F^1, J^1, K^1, &c.; and suppose the key to be moved so as to be covered by the first number or that which denotes eight cells of the battery, we then have the circuit closed by the contact springs so that the current may pass from the plate E, connected with the battery as explained, down the key to its pin and along the main wire to the opposite end of the train, here it passes up the key K^1 to the plate B^1, and thence by means of the contact and spring M^1, along the second main wire to the magnets under each carriage, finally completing its circuit to the opposite or zinc pole of the battery through the contact spring M, connecting the plates F and J. A similar circuit would be performed if the key was advanced to the second or third number on its guide, and the current increased to twelve or sixteen cells accordingly. To release the brake blocks the key is first held momentarily at R before being returned to its normal position, so that the current is reversed and the magnets demagnetized. It should be mentioned that a galvanometer is fixed near each keyboard, so that the guard at either end may know if the brakes are being applied. A line is also provided in each van, which may be fixed, if desired, to the key and the engine in such manner as to give the driver the means of applying the brakes in a case of emergency.

As a battery and keyboard are fitted in both vans it will easily be understood that the brakes may be applied from either end of the train. One guard only is therefore needed, as with the atmospheric brake, to attend to a train of ten or twelve carriages, because he may work his journeys both ways from the trail end of the train; the advantage of which is that when a stop is made at a station he is only required to pass throughout the length of the train once to perform his duty in an efficient manner. The conductors which connect the magnets and key-

board, &c., are No. 8, B W G, solid iron wire, and are coupled together between the carriages by means of the simple arrangement shown at Fig. 8. Its construction may be described as follows: The end of the wires to be coupled are fitted with a brass contact, one being circular in section and carrying four wires, each about 4 inches in length, which diverge until near their extremities, when they are sharply bent in a hook form so as to nearly again meet. The contact on the opposite wire is about 1½ inch in length, and in section of the form obtained by cutting away the angles of a square in such manner as to make angular grooves, along which, when it is desired to make the connection, the four wires above mentioned are made to slide until their hooked extremities are free to close over the shoulders formed by the contact wire, and complete the coupling.

We have now to describe the magnetic clutch fixed under each carriage and the arrangement of gear by which it applies the blocks to the wheels. Referring to Fig. 6, *a* is an axle of the carriage, *b* a horizontal shaft 2 inches in diameter, having a bearing in the bracket *c*, loose enough to allow a slight amount of lateral play to its opposite end, which is supported by the swinging arm or link *d*, hung from the framing of the carriage; adjoining this arm is a fusee, upon which is wound a chain having its other extremity connected to an arm of a lever to be mentioned hereafter.

On the shaft is placed a loose friction roller *e*, kept from lateral play at one end by a properly secured collar next its boss, and at the other by the fixed cast-iron disc *f*, to which is fastened the ½-inch wrought-iron friction plate, and the two electromagnets f^1 f^1. These magnets are made of soft iron formed as shown, and coiled with No. 14 copper wire, weighing 7 lbs. to each, while their poles, which pass through the disc *f*, are made flush with the surface of the friction plate next the roller. A recess in the roller contains an armature made of ½-inch soft iron in the form of a plate, on the back of which are two pins that fit into corresponding bosses cast on the roller, and thus cause the two to rotate together when motion is given to them by the revolution of the carriage axle. End movement is lowed to the armature so that it may approach the poles of magnets and friction plates and be in contact with them the circuit is completed at the battery. The main are connected to the magnets by the following arrangewhich allows the shaft to revolve without twisting them: collar *g* having its extremities bound by brass rings a groove, is fixed on the clutch shaft in the position the engraving. In these grooves are placed saddle

pieces, which clip the rings and extend upwards with a stem that is connected to the main wire by means of the terminals, supported on a cross-piece connecting the longitudinal and diagonal of the carriage. Along the shaft and protected by coils of hemp are taken the two wires from the magnets, one to each of the brass rings which encircle the collar *g*, so that the current from the battery may pass from the main wire down one of the stems to the magnets, and return in a similar manner to the adjacent terminal, thence along the main wire to the next clutch, and so on until the circuit has been completed throughout the train.

It should have been mentioned that the clutch is protected from dust or other foreign matter by means of a wrought-iron cover. Under each carriage, and fixed to suitable framing, are two levers *h*, *k*, in vertical and horizontal positions respectively. To the end of the former is attached the $\frac{7}{16}$-inch chain from the fusee on the clutch shaft, while another chain is connected to it nearer its fulcrum, so as to give a leverage in the ratio of about $2\frac{1}{2}$ to 1. The opposite end of this chain is joined to the extremity of the lever *k*, having, as will be observed, its fulcrum under the centre of the carriage, to which are attached, as shown, the tension rods that draw on the brake blocks, so as to give a further leverage in the ratio of 4 to 1. The blocks are of wood hung in the usual manner and applied to one side of the wheels only, so as to tend to draw them together. A proposed arrangement (Fig. 10) is shown for a series of cast-iron blocks on each side of the wheel, but which, as will readily be seen, is merely a further application of the principle just described, and therefore requires no explanation.

It will be understood from the drawings and what has already been stated, that the application of the brakes is effected simply by moving the key in the guard's van, so as to close the circuit and admit a current of electricity to the magnets, thus causing the armature to be attracted and held in contact with the friction plate, thereby communicating the motion of the friction roller to the shaft *b*, which will then wind up the chain, and through the intervention of the levers *h*, *k*, apply the brake blocks to the wheels. To remove the brakes the current is reversed, and the armature released by demagnetization, when the blocks are drawn off by the tension of the springs fastened to the headstocks of the carriage. A local battery is provided for each carriage, the conductors of which have in their circuit the magnetic clutch, and a keyboard fixed on the roof of the carriage. The circuit is kept open by means of a line which passes under a small pulley—attached to the key of the board—to the guard's van at each end of the train, where its

extremity is loaded with a weight to keep it taut. On the train parting anywhere the line is broken, when the keys are drawn over by means of small springs to the contact plates which complete the circuit and apply the brakes. The keyboard arrangement is shown at Fig. 9.

Having explained the construction of the brake, the author will now state his views as to the retarding force it is capable of offering to a train of ten carriages. He would first observe, however, that owing to no arrangement being provided for applying the apparatus to the engine and tender, it will be necessary for them, as in the case of the hydraulic brake, to be fitted either with the ordinary hand brake, Webb's steam brake, or some other kind equally suitable. If therefore it be stated that the electric brake is capable of stopping the train under consideration in the least possible distance, such statement refers to the carriages only. The author must not, however, be understood to infer that the magnetic clutch and other apparatus cannot be fitted to the engine, yet he considers that, as it would have to be capable of exerting three times the amount of retarding force as compared with that required for a carriage, together with the limited amount of space at the back of the fire box for the disposal of the apparatus, he would not be justified, in the absence of further details, in taking the brake as applied throughout the whole train.

The first question which presented itself to the author in investigating the power of this brake was the approximate amount of force required to be applied to the periphery of the friction roller so as to cause the armature to slide on the friction plate when eight, twelve, and sixteen cells of the battery were used respectively. To ascertain this, experiments were made by winding a strong line several times round the roller in such manner as not to increase the leverage in a sensible degree, and applying without jerking hand force doubled by means of a pulley, the pressure being recorded by a carefully-tested steelyard.

No. 1 *Clutch.*—(1) Mean force required to be applied at the circumference of the friction roller to cause the armature to slide on the surface of the friction plate with eight cells—stated to have been in use seven days—224 lbs. (2) Mean force with twelve cells, 304 lbs.

No. 2 *Clutch.*—(1) Mean force required to be applied to the circumference of the friction roller to cause the armature to slide on the surface of the friction plate with eight cells, 300 lbs. (2) Mean force with twelve cells, 448 lbs.

It will be observed that the force required with sixteen cells is not given, because not found to be greater than with twelve

cells, although trials were made with the batteries at both ends of the train. Attention should also be drawn to the great difference in the attractive power of the magnets, as this is a question of much importance, as will be shown in considering the objections to this brake. If we now take the maximum force that may be applied to the periphery of the roller without causing the plates to slide on one another, when twelve cells are used, to be $3\frac{1}{2}$ cwt., we have: Tension on chain connecting fusee with the lever h, in the ratio of radius of roller to radius of fusee and that due to chain, or as 4 to 1 $\therefore 3\frac{1}{2} \times 4 = 14$ cwt. This pressure is again multiplied by the levers h and k, $4 \times 2\frac{1}{2} = 10$ times $\therefore$ total force applied to the four wheels of the carriage $= 10 \times 14 = 140$ cwt. $= 7$ tons. Now, the total pressure required to be applied to wooden blocks fitted to the wheels of a carriage weighing 10 tons is, with the coefficient of friction at ·25, so as to allow for variation of weather, 7·20 tons, but in dry weather this variation is reduced to about 5 tons. Again, the total pressure required to be applied if cast-iron blocks be used is 9 tons, but in wet weather about 7 tons. From numerous observations made by the author he can testify to this brake being capable of locking all the wheels of a carriage weighing about 9 tons and moving at a velocity of about 20 miles an hour; and as friction is stated by the best authorities to be practically independent of velocity, we must consider it, in the absence of further trial, to be capable of doing likewise at higher speeds, and stopping the train therefore in the least distance after the blocks had gripped the wheels.

We have now to consider generally the objections which may be urged against the arrangement of this brake as now in use. The first one that occurs to the author is that if three cells are requisite for one carriage and a battery of thirty for ten carriages, the power to stop would be reduced one-third if exceptional traffic required the addition of five more carriages to the length of the train. It is true the locals may be brought into action also, but their application requires either the cutting of the rope that keeps the circuit open at their keyboards, or the lifting of the heavy weight attached to it in the van, either being an additional operation occupying too much time in a case of emergency. The second objection is the liability of the battery being put out of action entirely by one of the glass cells breaking from the vibration or concussion of the train; this evil is now receiving the attention of the inventor, and will no doubt be overcome. A third objection is the snap given to the chains connected to the levers h, k, in applying the brake blocks; this, however, does not hold good to the same extent as

in Mr. Clark's chain brake, because the fracture of a chain disables the apparatus of one carriage only, instead of that of the whole train. A fourth objection refers to the pressure on all the wheels not being the same. In the arrangements shown in Figs. 5 and 10, the lever being fitted under the centre transom of the carriage, requires the blocks always to move exactly the same distance; it therefore follows that if the wear of the blocks be unequal the pressure on the wheels will be unequal also, to such extent, in fact, as to require the rods, &c., connected to the lever to be capable of sustaining twice the tension that would be put upon them if the force applied was evenly distributed over the four wheels.

A fifth objection refers to no provision being made for the application of the brake to the engine and tender, because in a case of emergency it is very possible that the guard and driver would not apply their brakes simultaneously, and the train therefore not stopped in so short a distance as would otherwise be the case. It should not be forgotten that the engine and tender together are equal to about half the weight of ten carriages filled with passengers, and therefore, if we fit the brake to the carriages only we apply but two-thirds of the retarding force we should be capable of exacting if it was adopted throughout the whole train. A sixth objection is that the armatures and friction plates do not require in each case the same amount of force applied at the circumference of the friction rollers to cause them to slide on one another; differing in fact, as shown by the experiments, to the extent of 35 per cent., so that in one case we may have a total force of $4\frac{1}{2}$ tons applied to the brake blocks of a carriage, and 6 tons to those of another, however perfect the keyboard in the vans may eventually be made to regulate the power applied to prevent skidding the wheels for ordinary stops. The author would here mention that the armatures and friction plates have been reduced from $\frac{1}{2}$ inch thick to $\frac{3}{8}$ inch, after working for a period of from two-and-a-half to three months; he has been informed, however, that the reduction is partially owing to their having been "faced up" on several occasions. That considerable wear must take place may reasonably be expected, because the wheels must either be skidded or the plates rubbing on one another.

A seventh objection refers to the transverse pressure that is put upon the axle by the roller when the brakes are applied. It has already been shown that the maximum tension on the chain connecting the fusee with the lever *h* will be about 14 cwt. Now, from the arrangement it will be seen that this will be increased on the axle in the ratio of the distance of the roller from the bracket *c*, which acts as a fulcrum, to the distauce of

the fusee from the same point, or as five to seven about, ∴ pressure on the axle $= \frac{14 \times 7}{5} = 19{\cdot}60$ cwt., or nearly one ton. To this objection must be added another, *viz.* the wear of the axle due to the friction roller. The author is not prepared to say exactly how much this has been, but he found the diameter at this part to be about $\frac{3}{8}$ inch less than that immediately adjoining it.

To complete his description of this brake it now only remains for the author to point out how far it complies with the conditions laid down in his first paper:

(1) Although in the arrangement shown the driver does not apply the brakes, yet we must consider the condition capable of being complied with, as the keyboard may be fixed in a convenient position on the engine.

(2) A train of any number of carriages may be stopped by the driver in the least distance provided the battery power is made up in proportion to the length of the train, and it should be mentioned that the length of the train makes no difference in time required to apply the brake power throughout.

(3) The brakes can be applied by the guard from the trail end of the train as well as from the engine, and would act automatically by means of the "locals" if train breaks away at any part.

(4) The brake is not fitted to the engine, the remainder of this condition complied with.

(5) The application of the brake requires no exertion on the part of either guard or driver.

(6) Any derangement of the brake apparatus fitted to a carriage would not interfere—unless it affected the wires—with the action of the brakes on the remaining carriages. Even in this case the locals would meet the difficulty for the rest of the journey.

(7) The pressure would be applied to the whole of the blocks after the train had travelled 20 yards from the time of completing the circuit by the driver or guard. This distance is quite independent of the velocity of the train, as the wheels must make so many revolutions to wind up the slack of the chain.

(8) The brakes do not allow of any portion of the train being slipped; the slipping of one or more carriages would, without some further arrangement, apply the brakes to both portions of the train by means of the local batteries.

(9) This condition complied with, as the carriages may be coupled either end.

(10) Considering the apparatus generally, it can hardly be described as complicated. The arrangement under the carriages,

as illustrated, requires, however, improvement, as it may undoubtedly be rendered more efficient.

(11) An arrangement is shown (Fig. 11) for applying the blocks to both sides of the wheels; but it is defective, for if the blocks on the leading and trailing wheels wear unequally (no provision is made for their self-adjustment), the pressures therefore will be unequal.

(12) This condition not complied with for reasons given in objection 4. Neither is an elastic cushion provided to reduce vibration as much as possible.

(13) The apparatus may be considered as not liable to get out of order by atmospheric change.

From the description and above remarks, then, it will be seen that the electric brake, in its early experimental stage in this country, agrees with most of the conditions that are considered necessary to be fulfilled by continuous brakes. In justice to the inventor it should also be stated that there is good reason for believing that in the further application of this brake the apparatus would undergo several alterations that would render it still further capable of meeting many of the objections that have been raised in this paper, some of which, no doubt, will be explained to the meeting by General Chapin. In conclusion, then, the author will merely state—without expressing an opinion as to the cost of maintenance—that he believes this brake may eventually prove a success as far as efficiency is concerned. He would therefore ask those interested in the question of efficient brake power to give it that special attention its merits so fairly deserve.

In concluding his paper, the author will first refer to the subject of cost in fitting the brakes described to a train comprised of engine and tender and ten carriages respectively—spreading, for the sake of convenience, the total cost over the carriages only. Disregarding, then, the chain brake, as it is only applied to five or six carriages at most, we have:

(1) Cost of the hydraulic brake as fitted to the train on the Great Eastern Railway, including apparatus in van and everything requisite—with the exception of brake blocks and application to engine and tender—to make the whole complete, as given by Mr. Barker, 250*l*., or 25*l*. per carriage.

(2) The cost of the atmospheric brake as fitted on the Metropolitan District Railway—the arrangement for carriages to be the same as that shown in the drawings—including application to engine, tender, and carriages, complete in every respect, as given by Mr. King, the representative of the Westinghouse Company in this country, 260*l*., or 26*l*. per carriage.

(3) The cost of the electric brake, as fitted on the North London Railway, but not including the brake block gear or application to engine and tender, as given by General Chapin, 200*l.*, or 20*l.* per carriage. If due allowance then be made for deficiency in the application of some of the above to certain portions of the train, it will be seen that the cost of the apparatus in each case would be about the same, and that it would not be far short of 30*l.* per carriage, or 300*l.* for the whole train.

Another question of importance to be referred to is the annual cost of maintenance for each kind of brake. On this point, however, no reliable information can yet be obtained, for two reasons—one, the comparatively short time the brakes have been in operation; the other, because no systematic attempt is made by any railway company to ascertain which will give the most satisfactory results, either as regards first cost, maintenance, or efficiency. The time has now arrived, however, when this should be done voluntarily, or compulsion induced by an Act of Parliament requiring all trains to be fitted throughout with efficient brake apparatus. It is only necessary for three or four companies with widely different conditions of traffic—such as the Great Eastern and North London, or the North-Western and Metropolitan District Railways—to have trains composed of the same number of carriages fitted with brakes so as to satisfy the respective inventors of the atmospheric, hydraulic, and electric systems; and that in the first place trials should be carefully made under the same conditions for the purpose of ascertaining which brake could make the most efficient stops.

By trials the author does not mean the kind one sometimes sees and often reads about, where the velocity of the train is measured by telegraph posts supposed to be a certain number of yards apart, while the distance the stop is made in is calculated in a manner to make one almost believe that Bidders are common, but such as when the velocity in the final 300 yards, before applying the brakes, and the time required to stop in would be measured by the chronoscope, the distance stopped in properly ascertained, while all the other conditions, such as same place for experiment, kind of weather, kind of blocks, weight of train, and other considerations which affect the question, should be carefully attended to. The brakes should then be worked as nearly as possible to the same extent, the trials repeated; the effect of each apparatus on the wheels, axles, and the motion of the carriages, when applied, observed, and every item of cost recorded, so that in due time we should have tangible results which would tell us whether air, water, or electricity was the best medium for the transmission of power

for our purpose. The absence of such practical information must render the question always doubtful, and consequently lead to the waste of much money, because it is impossible to make a just comparison of the brakes' efficiency when one line, like the North-Western, tries the air brake; another, as the North London, the electric; while the Great Eastern, still true to itself, shows its affinity for the water.

March 10th, 1873.

JABEZ CHURCH, PRESIDENT, IN THE CHAIR.

CONTINUOUS RAILWAY BRAKES.

DISCUSSION.

Mr. G. SPENCER, in opening the discussion said, that one form of Mr. Clark's brake had been omitted from the paper. The form which had been described was what Mr. Clark called the positive brake, that was one in which the tension of the chain put the brake on. He had another form, which had been used for about two years on the Metropolitan Railway, and was still working there with satisfaction. In that brake the chain being loosened the brake went on by leverage. That was what Mr. Clark called the negative brake. By that system the third condition laid down by Mr. Fox was complied with. As regarded the question of skidding the wheels, he (the speaker) found among practical men a difference of opinion as to whether a wheel gave more power when skidded or when slightly revolving. He was recently at Manchester with Mr. Charles Fay, of the Lancashire and Yorkshire Railway, who was one of the first to introduce continuous brakes worked by the revolution of a shaft. Mr. Fay said there was no doubt that a wheel slightly revolving gave more power than a wheel absolutely skidded. He (Mr. Spencer) did not wish to be understood as expressing any opinion himself on the subject, but as he thought that it might be useful to have the views of a gentleman of experience like Mr. Fay on that subject, he had obtained from Mr. Fay the following letter:

LANCASHIRE AND YORKSHIRE RAILWAY,
Carriage and Wagon Department,
Miles Platting, Manchester, *7th March*, 1873.

DEAR SIR,

Referring to our conversation yesterday, I beg to state that about fifteen years since I tried some experiments with a train of three loaded carriages weighing 27½ tons as to whether by skidding or not skidding a train could be pulled up in the shortest time. The engine being a disturbing element was detached by a slip coupling at a given point and the following were the results:

Speed, 60 miles per hour, every wheel skidded: pulled up in 400 yards; repeated twice with the same result.

Speed, 60 miles per hour, wheels revolving: pulled up in 240 yards, or one-third less; repeated twice with the same result.

The experiments were tried on the Wakefield and Goole branch, on a portion of the line that was a dead level and over the same length of line.

I may remark that there are about 200 trains of continuous brakes on this company's line, consisting of from four to six carriages coupled up, and that no train is ever run without one or more sets of the continuous brakes, and which has been the means of preventing many accidents. I also forward extracts from Mr. Fairbairn's report of experiments, and am,

Yours respectfully,

G. SPENCER, ESQ. CHA^{S}. FAY.

P.S.—These brakes are working regularly on lines of heavy gradients, the steepest of which is on the Oldham branch, being 1 in 27.—C. F.

Mr. BARKER said he wished in the first place to direct the attention of the meeting to one or two points in connection with the coefficient of friction given by Mr. Fox. He would afterwards endeavour to answer one or two objections taken from the list of requirements of a good brake given by Mr. Fox. With regard to the coefficient of friction, he (Mr. Barker) hardly thought that ·35 was high enough for wood on iron when dry, he should say ·50 or ·60 would in ordinary practice be much more nearly the truth, more especially when it was borne in mind that on a dry day a considerable quantity of sand was taken up with the wheels. From his own observation he should say that ·50 or ·60 for wood on iron on a dry day was not too high, and ·20 on a wet day was not at all too low. According to Table C, No. 4, metal on metal, the coefficient given by Professor Rankine was increased when wet and clean to what it was when dry, *viz.* when wet ·30, when dry ·15 and ·20 only. According to theory there did not appear to be more adhesion between the cast-iron block and wheel than between the wheel and rail.

Secondly, with reference to the objections: First, as arranged on the Great Eastern Railway, undoubtedly the guard worked the brake, but by means of a cord the driver could apply it on emergencies; but working from the van was only for the convenience of traffic. The hydraulic system required four things to actuate the brakes—a tank, an accumulator, a pump, and a regulator. There were greater facilities for carrying that out on the engine, and moreover, it was so designed originally by him. No. 1 requirement, therefore, he thought was fulfilled by his (Mr. Barker's) brake, as was also No. 2. With regard to No. 3, if the driver worked the brake, then by means of a cord the guard could apply it in a case of emergency from either end of the train, and for working exceptional inclines an auxiliary apparatus might be placed in the van, and so arranged that on a break-away, a cord running along the train coming into tension should apply the brake. Conditions Nos. 4 and 5 were fulfilled in his brake; and with respect to

No. 6, a carriage could be isolated by simply turning a cock, and nothing but one of the 1-inch hose bursting could disable the brake, and the hose could be made with any margin of strength. They were made by a process which entirely prevented the canvas rotting by capillary attraction, which took place with the ordinary kind of tubes. Besides water preserved rubber, whereas air oxidized and destroyed it. As to condition No. 7, the guard or the driver, according to whether the engine or the van was fitted with the apparatus, could adjust the pressure from 0 to 260 lbs. Requirement No. 8 did not appear to be of great importance, since when a carriage was to be stopped on a journey, the side chains were dispensed with and a special slip coupling fixed. If required, a special coupling might be fixed on the hose so as to slip also, but that would hardly be necessary, as it would be more convenient to isolate that carriage and allow the guard to work the brakes of that one or more carriages so intended to be slipped. Condition No. 9 was fulfilled. No. 10 opened the question of complication. In the first place, the hydraulic system did away with all the cross shafts and levers incidental to an ordinary brake, and substituted a simple arrangement. It did away with all injurious strains, and gave a perfectly balanced pressure. The air brake accomplished that, but only at the expense of additional levers and shaft, &c. An objection might be urged to his (Mr. Barker's) employing two cylinders when one might be made to do. That, however, would be at the sacrifice of the principle involved.

With regard to complication in the van, the hydraulic system, like the atmospheric system, required, with the exception of a small tank, an accumulator, a pump, and regulator. On the Great Eastern Railway that was placed in the van, where it looked more and had two objections, *viz.* first, in the case of emergencies the driver would only indirectly have the power over it by a cord; secondly, a special man as inspector would be required, whereas the driver on the engine would be his own inspector. Again, the apparatus in the van weighed about 15 cwt., and extra weight on each carriage incidental to breaking 4 cwt., that included everything — taking twelve carriages; 48 cwt. × 15 cwt. = 63 cwt.; 63 divided among twelve carriages gave a little over 5 cwt. each, and that was considerably under any other system. Requirement No. 11 was perfectly fulfilled, and the importance of that would be still more appreciated in the case of cast-iron blocks, where, as Mr. Fox had stated, a force of nearly $2\frac{1}{2}$ tons required to be brought on to them when there was only $2\frac{1}{2}$ tons on the wheels to keep them in the journal, consequently giving rise to a most aggravated state of things. That was overcome in a measure by the air

ying the axle boxes together; but still the evil re-

garded No. 12, any desirable amount of elasticity might ned by an air vessel.

o No. 13, salt water would not freeze until zero, and de of calcium until 20 below zero, Fahrenheit: chloride ium cost about the same as common salt. The pipes not exposed to the atmosphere the corrosion did not take With regard to the tensional strain on the axle, Mr. Fox atisfactorily disposed of that matter. If there were any were opposed to it, the two extra cylinders required would ost more than about 2*l.* 10*s.* each.

Mr. J. T. KING said it was seldom that a scientific society had opportunity of listening to a paper containing so much nature thought, so well expressed with regard to the merits of the various brake devices which had been commented upon. It could not be said that the inventions had been brought forward by one interested in them, and that was an advantage. The paper had come just at the right moment. At the present time there was in the House of Commons a Government Bill which attempted to regulate the affairs of railway companies generally; and there was in the House of Lords a Select Committee appointed, upon the motion of Earl Buckhurst, to inquire into the prevention of railway accidents. Although that last Committee was only attempting to deal with the two questions of the block system and interlocking points and signals, it was a very fair subject for consideration, in regard to the prevention of accidents, whether it should not also deal with continuous brakes. The report so well put before the Houses of Parliament by Capt. Tyler, with regard to the so-called "accidents" that took place during the last ten years, showed that 2774 persons were killed from 1861 to 1871 and 8641 persons injured. It must not be forgotten that those returns were by no means complete, for previously to November, 1871, railway companies were not compelled to make returns of so-called accidents to their servants. He (Mr. King) might very fairly say with the leading journal that railway boards would be guilty of a very serious crime indeed if they neglected to take such precautions as were afforded by continuous brakes.

Although the author had put before the meeting a very excellent paper, still there were two or three omissions with regard to the Westinghouse brake; and in supplying those, he (Mr. King) would not say anything about any other brake. estinghouse brake was the only one largely in use in on long trains, and doing every day satisfactory work. n use on about 30,000 miles of railway, on thousands of

carriages and locomotives in the United States. It was the only brake, acting on long and short trains, as to which the cost of maintenance was absolutely known. Mr. Fox had said that the Westinghouse brake complied with most of the thirteen conditions laid down as those which must be fulfilled by a perfect brake. He had, however, stated as to the 3rd, that the Westinghouse brake was not so arranged as to enable the guard at the tail end of the train to apply it when he wished to do so. In practice it was found better to leave the guard with his ordinary hand brake; but if it was wished to give the guard power over the continuous brake, it would be a very easy matter to put an air reservoir on the tail van. That cylinder would be charged from the main reservoir on the locomotive, and in that way there would be stored up a power ready to be released should it ever be wanted. As to the 7th head, Mr. Fox said very truly, that he had some difficulty in ascertaining how long it took to bring the brakes into efficient full force action on the tires of the wheels; and he said that, taking fifteen carriages, he thought it would be somewhere about two seconds before they came into efficient action. Mr. Fox wished to make the experiment, and he (Mr. King) would be happy to afford him and every member of the Society every opportunity of doing so. He had that day travelled upon the Metropolitan District locomotive to observe how long it took to bring the brakes into operation on six carriages. Like Mr. Fox he had some difficulty in deciding how to begin; but at the suggestion of Mr. Simonds, who had had many years' experience with the air brakes in America, he went to a very good tell-tale, namely, the pressure gauge in connection with the air reservoir. Clearly the time it took the pointer or finger of the gauge to travel from the place where it first stood—that was the initial pressure—to the place where it stopped when the pressure in the reservoir brake pipes and cylinder was the same, was the full time taken to efficiently brake every wheel. That time, from actual observation, was only the fraction of a second; he (the speaker) did not know of any time measurer which could record it. As to the 11th condition, Mr. Fox spoke of bringing the pressure on both sides of the wheel. That was a matter of no moment. Any brake power could be arranged with blocks on one or both sides of each carriage, and on one or both sides of each wheel. The only disadvantage of having them on one side was the wearing away of the bearings; and that was a very small matter. In that respect, however, locomotive superintendents could please themselves.

Having reviewed, and to some extent explained, the objections raised by Mr. Fox, Mr. King said that not only would

the Westinghouse brake fulfil all the thirteen conditions laid down, but he would venture to say it would do more. For example, an excellent system of signalling between passengers and guard and driver could be used when the train was in motion. No connection from carriage to carriage other than the brake pipes was necessary. It was sufficient to have a bell-pull inside each carriage, an air reservoir underneath the carriage, and a wire or other connection between the pull and reservoir. On pulling the wire a signal would be given both in the guard's van and on the engine. As another instance, the store of compressed air could be used to raise water. By means of a pipe connected with a closed cistern placed in a well, the pressure of air on the surface of the water in the cistern would force it up another pipe delivering into the tender tank. That, he believed, was a matter of very great importance, more particularly in India, Russia, and Canada.

After all, the great points to be looked for in a continuing brake were (1) efficiency, (2) reliability, and (3) small cost of maintenance. The first and second points had been fully established in the case of the Westinghouse air brake, as was proved by its extensive use. The third—maintenance—might be put down at simply the cost of the oil and of the renewal of the flexible pipes. The cost of the oil was not very much; and the cost of renewing the rubber connections from carriage to carriage, giving each one a life of two years, would be a very small matter indeed. The actual cost of those items had been practically ascertained.

General CHAPIN said that the author admitted in the course of his paper that the electric brake fulfilled all the requirements except the 8th and the 12th. All practical engineers would admit that the requirements were very sensibly stated. The 8th requirement was that the brake should allow of any portion of the train being slipped; and even with regard to that the author had said that the brake could be easily re-established, after the slipping, by means of the local batteries. He (General Chapin) would ask why the local batteries were ever put in the train if it was not to exactly meet a case like that. In the case of a break-away, or of the removal of carriages from the train, the brake could be brought into play on each portion of the train. That could be provided for by a cord, but of course there must be a guard on each end of the train. The three-wire system would couple itself up and could be worked with the keyboard. The provisions made for slipping were in practical operation in America. Such a provision had not been introduced on the North London Railway, for there they were in the habit of running trains of ten carriages, and there was no case of

slipping. The brakes could be especially adapted to the kind of service which the trains would have to perform. He had himself constantly slipped a train into two pieces without touching the hand brake. That met the objection arising from the 8th requirement.

The 12th requirement was that the pressure on all the wheels of a carriage should be the same. He readily admitted that according to the arrangement which was shown by the plan, if one of the blocks should wear the pressure would not be equal, but the inequality would be very slight. The fact was that the pressure was actually balanced, and practically that was all that was found necessary. But to combat the objection it would be very easy to make the centre where the lever turned with a slight variation by giving it half-an-inch play. In a recent design not only had he provided for that difficulty, but also for the same difficulty which might be said to exist in putting the pressure on each side of the wheel and also on each end of the carriage. Mr. Fox had raised several objections to the mechanical arrangement of the electric brake. In that connection he (General Chapin) wished to state simply that, not having had the advantage of mechanical experience, he might have made some mistakes in the construction, which he would otherwise have avoided. The question, however, was whether those objections were of any real weight. He would therefore take them as they stood and see what they really were. The author said, "We have now to consider generally the objections which may be argued against the arrangement of this brake as now in use. The first one that occurs to the author is that if three cells are requisite for one carriage and a battery of thirty for ten carriages, the power to stop would be reduced one-third if exceptional traffic required the addition of five more carriages to the length of the train. It is true the locals may be brought into action also, but their application requires either the cutting of the rope that keeps the circuit open at their keyboards, or the lifting of the heavy weight attached to it in the van, either being an additional operation occupying too much time in a case of emergency."

The weight here referred to was heavy enough to take the slack of a half-inch rope running over a pulley. It did not require a very large amount of labour to lift such a weight, but if it was too much for the guard to perform it could very easily be accomplished in another way. In America it was originally done by means of two lines, and with springs so arranged that they did half the work. The cutting of the rope was needless. Even if twenty or thirty carriages were added to the train, since each carriage carried its own battery power, it was not necessary

...ls to the battery on the engine. Practically, eight or ...would do for ten carriages, and so they always carried ...ells, the addition of five or six carriages would not ...needful the working of the local batteries.

...econd objection was the breakage of the cells from ...on. In the first place, that was an impossibility; but if ...ard found that he had not sufficient brake power he could ...ock so as to bring in all the cups he required until he got ...wer. In order that the objection should hold good all the ...would have to be broken, and then there would still remain ...cups at the other end of the train. If those should fail also, ...e would still remain the local batteries; unless every cell in ...train was broken there would still be some battery power ...ft. However, as glass was liable to breakage he was now ...oving some batteries made with leather porous cups and copper ...ells. These would probably stand any shock which would arise ...from a collision.

"A third objection," said the author, "is the snap given to the chains connected to the levers in applying the brake blocks." That was simply a question of strength. If a half-inch chain was not found strong enough, an inch chain would be used. The fourth objection referred to the inequality of the pressure on the wheels, but that he had already spoken of in connection with another point. A fifth objection referred to no provision being made for the application of the brake to the engine and tender. It was easy to see that no such provision had been made on the North London Railway. It would necessitate the pulling of an electric clutch in sixty locomotives to rein one train. That would be an absurdity which no railway company would ever think of committing. A clutch could be applied to the engine, and the additional holding power required in consequence of the greater weight of an engine than of a carriage could be obtained in three ways. More wire could be added to the magnet; or another magnet could be added to the same clutch; or in the case of a very heavy locomotive a double armature plate could be put on the second. The clutch had never been put on an engine, for it was found that a train could be held without it.

A sixth objection was that the "armatures and friction plates do not require in each case the same amount of force applied at the circumference of the friction rollers to cause them to slide on one another." If magnets were of the same size, and were wound with the same length of wire, their holding powers would be alike. But the magnets which Mr. Fox had tried, got stripped in some places on the voyage from America, and that necessitated the rewinding of them, and there was not sufficient

No. 14 wire obtainable to cover them. Part of them were wound with No. 14 wire, and part with No. 18 or some other size. The wires also were of different lengths. But as long as the magnets were capable of skidding the wheels of the carriages to which they were applied, that was all that he considered necessary. No doubt there might be a difference of 35 per cent. between them, but if the weaker magnet was able to hold the wheels, he did not think there was any necessity to have its strength 35 per cent. more. The author mentioned that the armatures and friction plates had been reduced from $\frac{1}{2}$ inch thick to $\frac{3}{8}$ inch, after working for a period of from two and a half to three months, and that the reduction was owing to their having been faced up on several occasions. He (General Chapin) would observe that the facing up was necessary for perfect working, in order that the armature plate, which was of cast iron, should work against wrought iron. The men who made those to which the author referred, thinking to improve their working, put two pieces of cast iron together. The consequence was that they cut and required facing, and they had been faced twice. The iron was $\frac{1}{2}$ inch thick, and it was turned down to $\frac{3}{8}$ inch when the clutches were made. Mr. Fox found that they had worn away beyond that. He (General Chapin) had seen them working for a year and a half without any perceptible wear taking place. Mr. Fox, however, was quite right in stating that there was wear, for he (the speaker) had never yet found that friction failed to wear out iron in a greater or less degree. The cost of the plates might possibly be 10s., and if they wore a year and a half, the expense was certainly not very large.

The author next objected to the transverse pressure which was put upon the axle by the roller when the brakes were applied. In that connection, he (General Chapin) had only to say that the conclusion was not exactly correct. Allowing 14 cwt. pressure on the chain, the actual pressure would be about 17 cwt. at that point where the tire of the clutch struck the axle as now arranged. They were now shaping the axles of those they were having made, and were putting them farther on one side, in order to get rid of that strain; although it had never been found to weaken the axle or to produce any ill effect.

The paper continued: "The author is not prepared to say exactly how much this has been, but he found the diameter at this part to be about $\frac{3}{8}$ inch less than that immediately adjoining it." The fact was that those axles were not perfectly round. Moreover, they were made concave. It was necessary to get a flat place for the iron to bear, and therefore they were turned down to an even bearing. In conclusion, he would only say that

full examination into and criticism upon the electric

Yolland, R.E., said that there were some few points med to have been lost sight of in connection with the on of accidents. Continuous brakes were mainly used tropolitan District for the specific object of stopping a the shortest possible space, so that the railway might with the omnibus. He did not think that the question prevention of accidents had much to do with their use, arly all the Metropolitan railways which used continuous worked upon the absolute block system, and hence there comparatively small risk of collision between following ns. In the country the case was entirely different. Con- nous brakes were very little used in England, though some- what more in the north of England, on the Lancashire and Yorkshire line, than elsewhere; and on that line they were not applied for the purpose of a competing traffic between railway trains and omnibuses, but for the purpose of preventing collisions between following trains, when those trains succeeded each other at intervals of two or three minutes, those intervals being quite insufficient, without the absolute block system, to provide for the safety of the public. One important point had frequently been brought under his notice when he had had occasion to recommend—as had too frequently happened—the use of continuous brakes. That point was the effect of dividing trains, and adding to trains at junctions. The breaking up of trains at junctions had been the greatest obstacle apparently to the general use of continuous brakes. The great objection which had been urged was that in the case of trains running from London to different parts of the kingdom, there were so many junctions where carriages had to be added on or taken off, that it was quite impossible to adopt continuous brakes in such trains. Hence the experiments which had been recently made with the electric brake, the air brake, the hydraulic, and other brakes, did not seem to have tested those inventions in such a way as to prove that they were well adapted for general use in this country except on Metropolitan lines.

Mr. Fox had remarked in his paper that it was absolutely necessary that the driver should be the person—and it would seem, the sole person—to put the continuous brakes into operation. He (Colonel Yolland) must entirely dissent from that opinion. From inquiries which he had made into large numbers of accidents, he was enabled to state that it frequently happened that the guard, or sometimes a passenger, was the first person who became aware of an accident having occurred to a train. Hence he held it to be absolutely essential, with reference to

On both ends, and if necessary in the middle of the train, however, there were powerful apparatus, each working the brakes of two or three carriages, and which were quite independent of each other; so that if one should break, the others would not be affected. The whole were arranged with triggers, and so connected by a cord that they could be applied instantaneously together. While running at St. Petersburg with the directors of the railway, he had a handle for pulling the cord between his feet in the saloon carriage; and at a given word from Count Baranoff, the President, he pulled the handle and stopped the train in twenty seconds without the steam being shut off, and without saying anything to the guard or driver. It was not found at all necessary to apply those brakes to every carriage. When applied to two or three carriages at each end of the train and placed under the control of the two guards for ordinary traffic, the train could be stopped, in case of danger, with ease in from 150 to 200 yards, by either the engine driver, the stoker, or either guard. On any addition being made to a train, any station master could arrange the train with sufficient brake power to suit the gradients on that part of the line. The expense of fitting brakes to all the carriages in the railway stock would be enormous, and therefore it would be impossible to carry out such a system. Unless, however, a goods train going slowly could be stopped when approaching a crossing in the same proportionate space as an express train going rapidly, it would not avail the express train that it had got the most powerful brake in the world, if the impetus of the goods train could not be checked before fouling the line.

He had studied Captain Tyler's Reports for the last four years, and had worked out the details of almost every accident that had occurred; and it was thus easy to determine whether an accident might have been prevented or not, and if not, how much its effects might have been diminished by adequate brake power. Any brake not moved by mechanical power was liable to get out of order, and possibly to fail at the critical moment. That would be the case with one dependent only on a steam cock, an air pump, or an electrical communication. Mechanical brakes in which the momentum of the train was properly made use of, and so proportional that there was no risk of breakage, and which were applied in a proper mechanical way, were brakes that could be trusted. He objected to placing his whole reliance on any single thing, such as a steam pump, a chain, or an electric current in descending a steep incline, such as that on the Poti and Tiflis Railway, where the gradient was 1 in 40 for five miles. At present there was a large number of special brakemen there who were solely employed to take the

trains down, one being on every carriage. No one, he thought, in such a case, would like to send those men away and trust solely to an air pipe or an electrical communication. The reason why Heberlein did away with the continuous chain, several years ago, was simply because he found that the slack required too long a time to wind up; and that if the chain broke the whole train brakes were useless. He (the speaker) hoped that the Heberlein brake would soon have a fair trial in England.

Mr. Fox had asked him to state his experience with cast-steel brake blocks. He (Captain Fairholme) could only at present say that cast-steel brake blocks were being adopted in Switzerland and Germany in large numbers and with the greatest success.

General CHAPIN said that each railway company must decide for itself the amount of brake power which was necessary for its traffic. As to the question of "sandwiching" (and there was no other word that would express the practice) he had himself sandwiched a train of fifty-six carriages with eight goods wagons provided with electric clutches. The cords from them ran through the keyboard carried on each carriage to the locomotive; that gave the driver the control of all the brake power of those eight clutches. The control of the clutches might be given to the guard or to any man in any part of the train. It was one of the qualities of the electric brake that it could be worked not only from either end of the train, according to one of Mr. Fox's requirements, but also from any seat of any carriage. That arrangement was being carried out in America, and he should have it in operation in this country in a couple of months. There was no difference in that respect whether the brake was continuous throughout the train or applied only at intervals.

Mr. S. W. JOHNSON, Engineer-in-chief of the Great Eastern Railway, said that the hydraulic brake was a very good brake, and answered all the purposes which he required it to fulfil; it had worked for two years without much repair. On his line they had tried both that brake and Clark's. The latter had given them a great deal of trouble by the chains breaking, and they had tried both kinds of Clark's brake. The hydraulic brake had given them no trouble, and he believed that it was likely to be more generally adopted than it was at present.

Mr. C. H. MACKIE, with the permission of the President, read the following [illegible]s: I propose to inquire how far the four systems of b[illegible]mply with Mr. Fox's conditions, taking those condit[illegible]y stand. But before doing so I would draw attent[illegible]ox's statement, that should his thirteen

conditions be fulfilled the system fulfilling them would be practically perfect.

Before adverting to the air brake I think that, owing to the extended use of the apparatus, it may safely be said that the inventors have quite mastered the principle and general arrangement; and that they are introducing their brake into this country without doubt in its very best form.

With regard to General Chapin's electrical system the mechanical arrangement is very crude, and, as General Chapin has stated, his clutch was applied to the chain brake gear on the North London Railway by way of experiment, simply to demonstrate the principle, which, I may add, it has done most satisfactorily.

I have seen, however, another design of gear, besides the two before the meeting, which gives an absolutely compensated arrangement, both as regards the wheel base and the blocks on either side of the wheel. It is to this system I propose to apply Mr. Fox's conditions.

Mr. Barker's system, I think, admits of no great improvement; I will therefore take that as it is. Of Mr. Clark's chain system I will speak of the arrangement of gear as applied to a train on the North London Railway. I will now proceed to inquire if any of these systems is practically perfect, taking Mr. Fox's conditions seriatim.

Condition No. 1.—The electric and atmospheric are the only brakes that comply satisfactorily with this condition; the former having its keyboard on the engine, and the latter its motive power there. Mr. Fox says the hydraulic apparatus can be connected to the engine by means of a cord, but at best this is a clumsy and imperfect contrivance.

Condition No. 2.—In this condition Mr. Fox says the brake should be capable of application, whatever its distance from the engine. The electric alone complies, being capable of application over an unlimited length of train. Mr. Fox, in his summaries, entirely sets aside his own condition, for of the atmospheric he says, "a train of reasonable length can be brought to a stand," &c.; and of the hydraulic, "the brake can be applied to a train of reasonable length."

Condition No. 3.—This condition, in my opinion, is not complied with by any system but the electric, which can be applied from as many points as desired; and a train fitted with it is capable of being broken into several portions, the brake gear of which portions will go on automatically. With regard to the other systems, in the event of a train breaking away the brake on the broken portion is not only not self-acting but absolutely useless.

Condition No. 4.—The first part of this condition is fulfilled by all the systems; the second part, which in my opinion is the main condition, is fulfilled only by the electric system, as was shown in the previous condition.

Condition No. 5.—This condition is fulfilled perfectly by the atmospheric, hydraulic, and electric systems. Mr. Clark's brake, however, requires more power to be exerted than any other, but not so much as to render it very objectionable.

Condition No. 6.—This condition is only fulfilled by the electric brake. For should a cylinder or reservoir burst or leak severely, or the pump apparatus fail, the whole atmospheric brake is either very impotent or absolutely useless. This also applies to the hydraulic system; and should the chain in Mr. Clark's system break, that apparatus is also rendered useless. Mr. Fox allows that the air brake practically complies here, because the air pipes are in duplicate as though the whole apparatus consisted of air pipes alone; but even if the cylinders, reservoir, pump, &c., are in duplicate also, still the apparatus has only two chances.

Condition No. 7.—This condition is practically an impossibility, and were it even possible it would be a great disadvantage, because the sudden application of the blocks to the wheels with the full force is almost certain to skid them, and thereby lose a large amount of retarding force; whereas a gradual application, though prompt, will doubtless develop the greatest retarding force without the liability to skid. I suppose Mr. Fox meant simultaneously for instantaneously. The electric brake gets its blocks into operation quicker than any other system, namely, in 20 yards at the utmost. It applies them practically, simultaneously, and has also the advantage of applying them gradually. With regard to the atmospheric brake, Mr. Fox says it takes two seconds to get it into operation, which two seconds at 60 miles an hour correspond to 58 yards; thus reducing the efficiency of the brake to a stop in 278 yards instead of in 220 yards.

Condition No. 8.—This is a vague condition. I suppose Mr. Fox intended the piece of train slipped should have its brake apparatus perfect; if he did, the electric system appears to be the only one complying with the condition.

Condition No. 9.—This is another vague condition. If Mr. Fox when he says "carriages" means any carriages not fitted with the continuous brake apparatus, I think the electric system again only complies. The operation being simply to run some dead wires through [illegible]tervening carriages or goods vans.

Condition No. 1[illegible] this condition stands there may be a considerable diff[illegible] opinion as to what complicated parts

are. Mr. Fox says of Mr. Barker's brake, "The apparatus in the van is much more complicated;" whereas of the air brake he says, "It may be considered devoid of complicated parts." As far as complications are concerned I do not see much difference between the two systems. The chain brake, however, is very simple, and the electric system is also free from complications.

Condition No. 11.—This condition is perfectly fulfilled by the electric brake where the wheels are absolutely in equilibrium. Mr. Fox considers the hydraulic system to fulfil this condition, but I think that an axle is capable of division into right and left side; and as Mr. Barker put his blocks to only one wheel on an axle at the expense of the other, thereby tending to uneven wear, I think it can scarcely be allowed that the hydraulic brake does fulfil this condition. In the atmospheric and chain brakes the wheels are forced apart with the full pressure on the blocks.

Condition No. 12.—I think it would have been as well to have left out the second part of this condition, or at least to have made it a separate one; I will however call it 12a. Then condition 12 proper is fulfilled by the electric, atmospheric, and chain systems.

The second part, or 12a, is only complied with by the hydraulic system, where the brake blocks really abut on the water in the cylinders, which is in communication with the spring reservoir. But I think, considering the distance this elasticity has to travel, it cannot possibly be used. Again, in the atmospheric brake there is air at 50 lbs. pressure per square inch acting on the blocks at a considerable average, and it is said to be elastic. I quite agree that it is elastic, but as long as there is no force equal to the elasticity it might just as well be perfectly rigid. Again, this elasticity to be beneficial should allow the springs free play, but when the arrangement of blocks and the friction of the axle box against the horn plate, or 2 tons on 8 square inches, is considered, it will be seen that this elasticity cannot possibly allow the springs any play at all.

Condition No. 13.—This condition is fulfilled by the electric, atmospheric, and chain systems. Mr. Barker's brake being liable to the action of frost some saline or alcoholic solution is used, and no doubt a very injurious corrosive action will be set up.

Having thus reviewed the various systems, it appears to me that there is only one which meets all the requirements of a railway brake, and is therefore practically perfect, and this is the electro-magnetic system. Of the others the atmospheric appears to meet five conditions only; the hydraulic brake complies with only three conditions; and the chain system, five.

Mr. BARKER asked Mr. Mackie to explain what took place when a saline solution or an alcoholic fluid was used in the hydraulic brake to prevent the effects of frost.

Mr. MACKIE said it was generally admitted that alcoholic or saline solutions in contact with brass, iron, or other such metals, set up a corrosive action. He would like to add a remark as to the cost of working the atmospheric brake as compared with that of working the electric brake. Mr. Fox stated that it required 5000 cubic feet of steam at 110 lbs. pressure to work the air brake for a day on the Metropolitan District Railway. The electric required thirty cells, forming the batteries, to work it for a fortnight on a train on the North London Railway. The cost of the electric system would be 5*d.* a day including labour. The cost of the coal used to raise 5000 cubic feet of steam at 110 lbs. pressure would amount to at least 2*s.* 6*d.*, and then there was the cost for oil, packing glands, &c.

Mr. BARKER said, with regard to the corrosion which was said to be caused by a saline solution, that Mr. Johnson the other day had a pipe removed which had been in use, and found that no corrosive action had taken place. He (Mr. Barker) accounted for that by the fact of the surface in contact with the saline solution not being exposed to the atmosphere.

Mr. WILLIAM ADAMS asked whether Mr. Barker usually mixed salt or alcohol with the water which was used for his brakes, or whether it was only used exceptionally, when required.

Mr. BARKER said that during the winter months a semi-saturated salt solution was regularly used. The quantity was increased to saturation during frost.

March 17th, 1873.

JABEZ CHURCH, PRESIDENT, IN THE CHAIR.

CONTINUOUS RAILWAY BRAKES.

ADJOURNED DISCUSSION.

Mr. PENDRED, in resuming the discussion, said that four different systems of brakes had been described in Mr. Fox's paper, very lucidly and with great impartiality. The impartiality was apparent from the fact that representatives of all the brakes were present, and they had only taken very general exception to anything Mr. Fox had stated. Although there had been considerable discussion upon the paper, there yet remained several points for further elucidation. It should first be considered what the inventors of continuous brakes proposed to do. It was not suggested that any one of them proposed to do more than arrest the revolutions of the wheels of a train. They all took the old brake blocks in a form totally unaltered, and they had really done little or nothing but devise means by which it could be applied simultaneously, or nearly so, to all the wheels of a train. Was it then to be assumed that those inventions represented the only or the best form which a brake could take? He remembered a proposition made some years since to cast an anchor from the tail end of the train and bring it up all standing. The inventor was much incensed because no company would take up his invention. It was suggested that he should apply to the Great Western Company, and his answer was very striking. He said, "I will not go to the Great Western Company because they use continuous sleepers. There are no cross sleepers, and my anchor would drag without cross sleepers to hold it." A very short time ago a gentleman brought to him (Mr. Pendred) an "improvement" on that brake. The inventor argued that if he used an anchor in the ordinary way, and that anchor held, he should either break the rope or the couplings, or pull the tail end out of the train. He therefore applied a friction brake to a windlass, and carried the coil of rope and the drum in the guard's van. He applied the brake very dexterously to the rope, and so pulled the train up, or pulled something else up, it did not matter what. That, of course, was an absurdity, but at all events the inventor had some originality as far as the brake proper was concerned. The

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He next came to the Westinghouse brake, and he would venture to maintain that that brake was the only one of the four which carried with it a practical evidence of absolute success. He did not for one moment pretend that it was perfect or free from slight defects, but the Westinghouse brake exerted a remarkable claim on their attention, as being the most extensively used continuous brake of which they had heard. It had been alleged to give satisfaction on 7000 miles of railway in the United States, and he knew as a fact that the Westinghouse Brake Company had now at work at Pittsburgh a factory employing 300 hands continuously, who were engaged in the manufacture of the brakes and pumps. That was a fact to which considerable importance ought to be attached in estimating the value of the various brakes which had been described, and deciding whether they were or were not likely to succeed in this country. There were possibly other brakes which were as good, but the fact that they were so had not come before railway companies in this country. There was no evidence before the Society that they had been used or tested on so large a scale as the Westinghouse brake. Railway men very naturally and very properly adhered to precedent, and therefore he should say that the Westinghouse brake was the brake for railway men to take up, because its history was so satisfactory.

He now came to Mr. Olmstead's electrical brake, and he approached it with a great deal of hesitation, because he was not an electrician. It had been tested, as he understood, on a very considerable scale in the United States, but the results of that testing the meeting had not had placed before it. Some information as to what the Olmstead brake had really done in the States was very desirable. He had not seen it at work, but it appeared to him to combine the effects of Clark's brake, inasmuch as it used a chain which was liable to snap, with all the objectionable features supposed to apply to the use of electricity in railway train communicators. As to the electrical part of the subject, he should only say that he was afraid that the details of wires, couplings, and electrical appliances generally were not very suitable for the ordinary class of railway porters.

In conclusion, Mr. Pendred called attention to the fact that no information had been given as to the cost of maintenance of the various brakes, and that, he submitted, was a most important point. A brake might be as good as it was possible to make it, but if the cost of maintenance was excessive, or if it was likely to get out of order and require continual attention, it was unsuitable for general work. And it was one thing to use or try a brake or any other invention under the inventor's own eye, and another thing to use it extensively under all possible exi-

genera of weather and in the hands of men who were not likely to look after it with care. Therefore he trusted that some information would be supplied as to the cost of working and maintaining the various inventions brought so ably before the meeting by Mr. Fox.

General CHAPIN said that he agreed with the last speaker that cost of maintenance must be considered as well as the first outlay. For some reason which he (General Chapin) did not understand, Mr. Fox had added to the first cost of the various brakes: to one, 4*l.*; to another, 5*l.*; and to the electric brake, 7*l.* The great question, however, was the cost of maintenance. The electric brake had run four months on the North London Railway, making 250 stops a day, and running 18 miles a day, without any failure, and the actual cost, as proved by the books of the company, was 1½*d.* per day per train of ten carriages. That included the maintenance of the batteries and repairs of the batteries (consisting of re-silvering once a fortnight), the wages of the men who performed the work being charged at 6*s.* per day. The actual cost of Mr. Clark's oil from of brake was 20*l.*, and the maintenance (as recently shown to Mr. Clark) had cost 50 per cent. per annum for the last nine years. The cost of the Westinghouse brake, taking the sizes given by Mr. Fox, was 2*s.* 6*d.* a day for steam, without allowing for oil, packing, or breakages.

Mr. H. ALFRED VARLEY said he gathered from the paper under discussion, that the mechanical, the atmospheric, the hydraulic, and the electrical brakes fulfilled all of them in a greater or less degree the conditions which Mr. Fox had laid down in his paper as essential in a railway brake. The question to be determined to be, Which of these brakes would best stand the test of actual work? When discussing the merits of the inventions now under consideration, it must not be forgotten that the conditions of working on a Metropolitan railway were [illegible] from those on the main trunk-lines of the country. [illegible] travelled on Metropolitan lines were short, the [illegible] all alike, the trains were seldom or never broken up, [illegible] dall and the workshop were never far away, [illegible] operation was therefore comparatively easy. On [illegible] the rolling stock was of a very composite cha- [illegible] were continually being remarshalled and [illegible] with the stock of other companies, the distances [illegible] and therefore efficient maintenance and [illegible] were much more difficult.

[illegible] and cost of maintenance, he believed the [illegible] would be found to be far easier and much less [illegible] e atmospheric or the hydraulic [illegible]

brakes. The hydraulic and atmospheric brakes required a complicated system of pumps underneath the carriages and accurately fitting couplings, for the efficient maintenance of which skilled labour and constant supervision would be necessary, whilst for the electrical brake all that was required was a galvanic battery and flexible conductors for connecting the vehicles together, the connection between vehicle and vehicle being made by metallic surfaces simply touching one another. Carriages were frequently left standing for months in an exposed siding, and to meet the exigencies of railway traffic it not unfrequently happened that those vehicles were marshalled without previous examination. A system which required only metallic surfaces to touch one another for the efficient connection of the carriages would be more likely to be found in order under such conditions than any system involving pumps, the maintenance of stuffing boxes, flexible air, or water-tight couplings capable of withstanding pressure. He himself had devoted many years to the study of electrical science and its practical utilization, and he had successfully applied electricity to railway trains for the purpose of establishing communication between the passengers and the servants in charge of the trains. The system in which he was interested was fitted to the Royal train in which Her Majesty travelled to and from the North in 1866, and had been in use on that train for six years; it was also tested on an ordinary passenger train, which made two journeys in the twenty-four hours between London and Wolverhampton, running daily 250 miles, and continued in use on the train for nearly two years, during the whole of which time the train was started from all stations at which it stopped by means of the electrical apparatus, the working of which was recorded by the guards. In that way the electrical communication was tested, and its behaviour recorded twenty-two times daily. Nothing could be more satisfactory than the working of this system as shown by the guard's journals, whilst the expense of maintenance was also nominal. There was no doubt that a most important element to ensure the success of an electrical system when applied to trains in motion was the coupling which connected the vehicles electrically together. He had referred to his experience on a train running under the ordinary conditions of traffic, to show it was practicable to maintain at a very small expense an electrical circuit in railway trains.

Mr. CLARK said that the chain brake which had been described by Mr. Fox in his paper was that which he (Mr. Clark) introduced two years ago on the North-Western Railway, but did not represent the brake in its most recent form. The first brake, however, had answered all the essential requirements, and

had fulfilled its purpose very well. Five weeks ago he was requested by officials of the North-Western Railway to design a brake for the main line. This he did, and three weeks ago it was out with half-a-dozen carriages on trial, running from Crewe to Rugby. The trial having proved satisfactory, an order was passed for the stock to be fitted with it. There was great simplicity in its construction, only eight parts being required in a brake for a four-wheeled carriage.

Considering the class of men who had to couple the trains, brakes should be of the most simple construction, and so very obvious to the senses that the men could not fail to understand them. In case of leakage in an air, water, or electrical brake, it was difficult to discover the defect. The chain brake was applied by the driver from the engine by means of the ordinary communication line. Upon that being pulled back a few inches the lever inside the van was slipped, and a weight of about 45 lbs. dropped about 4 inches, and brought the friction spindle in contact with the axle of the van, and that wound up the chain in a very short space of time. In the trial to which he had referred the speed was 50 or 60 miles an hour, and the train was pulled up in fifteen or twenty seconds. They stopped fifteen times on the way, three times with full steam on, and very little time was lost by the stoppages. The wheels were skidded slightly. The driver had no power to regulate the pressure applied to the wheels, but where the greatest effect was required he (Mr. Clark) did not stop short of the skidding power. He believed that if the wheels skidded at a very high rate the retarding effect was not so great as if they were just allowed to run. At 15 or 20 miles an hour the greatest effect was obtained by skidding. The new brake could be worked on any number of carriages, and the driver could drop the levers of four or six vans at pleasure.

At the last meeting of the Society Mr. Johnson said that his (Mr. Clark's) brake had caused him a great deal of trouble on the Great Eastern Railway. He (Mr. Clark) admitted the fact, but he would remind Mr. Johnson that the brake had not been working under his (Mr. Clark's) supervision. Mr. Barker's brake, on the contrary, while working on the Great Eastern Railway had been under the care of one of Mr. Barker's own men.

Mr. JOHNSON said that he did not wish to detract from the merits of Mr. Clark's brake, but he thought it only fair to state that one of Mr. Clark's own men had been in charge of it during a portion of the time it had been used on the Great Eastern Railway.

Mr. DRUITT HALPIN said that with reference to the question

of the power of brakes in retarding trains, whether the wheels were skidded completely or were permitted to revolve slowly; some very careful experiments had been made on the Eastern Railway of France by three experimenters, namely, Messrs. Vuillemin, Guebhard, and Dieudonné. They made the trials in two different ways: first, by attaining a known velocity with the carriage whose resistance had to be determined; then shutting off steam in the case of an engine, and observing the distance passed over when the vehicle had come finally to rest. Knowing the amount of mechanical work stored up in the vehicle when the impelling force ceased, it was easy to arrive at the resistance overcome during the period the vehicle was coming to rest. Secondly, by registering the tractive resistance when the engine, vehicle, or train being experimented on was running steadily by a dynamometer. The general result was that when the wheels were totally skidded the coefficient of friction of retardation was 0·128, and for the wheels partially revolving it rose to 0·192. Thus the effect was much greater when the wheels were slowly revolving. That was the practical conclusion at which the experimenters arrived, and they reasoned it out in the following way:—Taking the mechanical work stored up in the train to be the same in both cases—and also assuming the weight and the velocity to be the same—it was easy to prove that the friction must be greater when the wheels were revolving, because the mechanical work done in bringing the train to rest was the weight multiplied by the distance travelled, multiplied by the coefficient of friction, whatever that might be. As the weight was the same and the distance was less, the coefficient of friction consequently must be greater. As to the velocities attained during those experiments, they varied from 46 to 39 kilometres per hour; and the retardations ranged from 760 kilos. to 880 kilos. with the wheels skidded.

In the second series of trials, the velocities varied from 33 to 64 kilometres; and the retarding forces ranged from 1030 to 910 with a given weight of train. The mean of the retarding force with the skidded wheels was 817 kilos.; and the mean with the revolving wheels was 1100 kilogrammes. The experimenters accounted for the difference by supposing that as the wheels were partially revolving against the rails, a kind of detent or ratchet-wheel was formed on the wheel of the vehicle which had to be ground off as the wheel passed over the brake block; and thus power was absorbed.

With regard to continuous brakes, he might mention one which had not been brought before the meeting. That was Naylor's brake, which was not now before the public; but that was due chiefly to the illness of the inventor. It had been

successfully tried in some experiments made with it at Sevenoaks, the velocities varied from 35 to 57 miles. The train consisted of four well filled coaches fitted with the brake, and a four-wheel coupled engine and tender having its own brake. The results were as follows:

Incline.	Gradient.	Speed.	Stopped in	
			Distance.	Time.
Down ..	1 in 101	43 miles	460 yards	38 seconds
Up ..	1 in 101	43 „	212 „	20 „
Down ..		57 „	760 „	60 „
Level ..	—	50 „	700 „	60 „

Naylor's brake had certainly an advantage over Clark's, inasmuch as there was no perceptible chatter or vibration when it was suddenly applied. They could not tell when the brake was put on. It had all the elements of simplicity, being easy to couple, and if any part of the train broke away or became detached, the brake came into action automatically. The action was negative, that was to say power was required to take the brake off; and springs were used to assist in producing the pressure on the brake blocks, and to maintain that pressure uniform during the descent of the brake levers. Any number of carriages might be coupled together when using that brake without impairing its efficiency.

Mr. J. BERNAYS said that the conditions laid down by the author of the paper were of very great importance for railway brakes; and future inventors would do well to adopt them as a basis on which to proceed. It was therefore desirable that those conditions should be discussed, as they really formed the starting-point of the whole subject. He had carefully considered them, and to four of them, namely, Nos. 1, 2, 10, and 11, he had some objections to make. Condition No. 1 stated that as the engine driver had charge of the motive power of the train, it was necessary that he should also have charge of the retarding power. But the driver and stoker were really the hardest worked men on the train, in fact they were generally supposed to be overworked. There was therefore an objection to more work being thrown upon them. He had recently counted the number of handles which had to be attended to by the driver on the foot plate, and he found that it was twenty-two. In addition, the drivers had to attend to the signals and the gradients. He therefore thought that it was better that the engine driver should [illegible] the intimation to the guard when to apply the brake with [illegible] he should have to apply it himself. There were,

however, countries where the line was not properly fenced off, and where in consequence cattle browsed on the line. Of course in such a case it would be well to let the driver have some retarding force at hand. He (Mr. Bernays) should therefore propose that the word "advisable" or "desirable" should be substituted for "necessary."

With regard to condition No. 2, Mr. Fox had explained that a train weighing 150 tons, made up of ten carriages and the locomotive and tender (100 tons and 50 tons respectively), and going at 60 miles an hour, could be pulled up within 220 yards if all the wheels had brakes, and he had said that such 220 yards was a perfectly safe distance. He (Mr. Bernays) believed that it was unnecessary to give more than sufficient power to pull up in that distance; and to pull up a train going only 30 miles an hour it would not require that all the wheels should be under brake power. In other words, the above train going only at 30 miles could pull up a further load of about 450 tons within the 220 yards. What he meant was, that as 220 yards was a sufficiently short space in which to pull up a train, it was not needful to have every wheel fitted with a brake if the speed travelled was less than 60 miles an hour. Therefore the word "desirable" should again be substituted for "necessary" in the 2nd condition. The 10th condition was, of course, the principal one, but he should wish it to be extended by the addition of the words, "and if out of order the defect shall be easily detected, and easily remedied on the road." The 11th rule he should like to omit altogether or to have reversed in its meaning. The application of the brake blocks ought not to be attended with pressure on both sides of the wheel. He believed that all the blocks ought to act only on one side of the wheel. The wheel and axle were quite independent of the framing when they ran, but as soon as the brake was applied, the effect was like that of taking the wheel up with tongs. The wheel could not possibly move without transmitting identical motion to the carriage frame, and hence arose an unpleasant vibration. He believed that in that respect a single brake on one side was far superior, because it allowed the springs to be free to a great extent, though, of course, not entirely so. Mr. Fox had laid stress on the fact that there was a great side strain. This, however, was not so large as it appeared, for the moment the wheels were skidded, the speed of the axle was considerably reduced, and there was a dead pressure only left which did not produce much wear.

With regard to the brakes themselves, as a mechanical engineer he should prefer mechanical means for the application of a brake, as, for instance, in Clark's brake. He did not mean to

say that that was the best brake, but still he should consider that that which was the most simple, most inexpensive, and the most easily repaired by the most unskilful men was most likely to be successful in the end. So far he therefore preferred the chain brake. There were, however, many excellent points in the hydraulic brake and the air brake; and where they were confined to Metropolitan traffic, and were under the attention of experienced men, there would be no great objection to them. But on country lines it would not be easy to detect a defect or to repair it in those brakes, and therefore the more plainly mechanical brakes would best answer in such cases.

As regarded the hydraulic brake he would ask why a somewhat similar arrangement of accumulator as in the air brake had not been made use of. The idea of using steam for weighting the accumulator must, or ought to, have occurred to the inventor. As to the electric brake, the only real fault he had to find with it was the difficulty of finding out where a defect lay. He believed that if it became deranged on the road, there was not one of the attendants who would know how to go about even the finding out the seat of the defect. Most electrical appliances failed in working through a failure of contact; and if there was a want of contact in one single point the whole brake would be thrown out of gear. The electrical loom failed in practice simply through defective contact. On the other hand, the electrical brake had not had a very long trial, and would no doubt undergo improvements in many of its details.

General CHAPIN said that obstructions occurred on railways in England which were not due to cattle, and which made it necessary to stop a train within 220 yards. Mr. Fox's proposition was that it was possible to pull up at 220 yards when going 60 miles an hour, but he did not assume that it was never highly desirable to pull up in a shorter space. Drivers would sometimes be glad to pull up in 20 yards. Mr. Bernays had objected to the working of the continuous brake being given into the charge of the driver. The twenty-two handles which had been spoken of were not handles which the driver was constantly using on a journey. He (General Chapin) considered it a great advantage in the Westinghouse brake that the driver always had to apply it, for constant use would induce such a habit on the part of the driver that as soon as he became aware of an obstruction his hand would naturally first seek those handles which were used in the stopping of a train. Mr. Bernays had spoken of contact in the electric brake. The principle of that brake was that each carriage should carry its power in itself, so that in a train of ten carriages if contact failed in nine carriages the brake would still be operative on the remaining

carriage. The large battery which was carried on the van, and which would properly be carried on the locomotive if the whole train was fitted up, was merely a battery of convenience for station work, and had nothing at all to do with the batteries of safety which were the batteries in the separate carriages. It was hardly probable that in a train of several carriages contact would fail throughout in consequence of any accidental jar or breakage. He agreed that if the brake depended entirely on the through wires running from the van, it would be open to a very grave objection; and it was to obviate that objection and to enable the brake power to be used in any position that the battery service was kept up in each carriage.

Mr. VARLEY said the act of testing the electrical communication throughout a train for the purpose of discovering a defect might be reduced to a simple mechanical operation, which could be performed by a man who had no knowledge of electricity.

Mr. PENDRED asked General Chapin what system of cord he used for working the brakes, as it would be very desirable in this country to get a good system of cords for use in signalling.

General CHAPIN said that in America the cars were made differently from those used in England, and that fact had caused some mechanical difficulties in applying both the Westinghouse brake and his own. In some cases two cords were used for the electrical brake, and in some cases only one. There was always a cord running through the middle of the train, and that was connected with the bell; each carriage carried its own cord. When two cords were used for the brake one ran through the keyboards on one side to put the brake on, and the other ran through the other side parallel to pull it off. The pull-off cord was the ordinary signal cord, and this when pulled simply pulled the bell, it had no effect on the brake whatever; the other cord put on the brake. He believed that the brake seen by Mr. Fox had only one cord, with a spring on one side of the keyboard, with a small weight at one end of the train which took the slack between the carriages, so as to keep the cord always in tension. There were three or four ways of making the contacts. By means of the three-wire system it could be done without any cord at all, an extra battery being run with each carriage.

IN THE CHAIR.

AY BRAKES.

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he did not see the necessity of applying the brake to every carriage.

The third condition, or that which required the brake to be applicable from the rear of the train, was desirable in case of a break-away, and ought to be carried out if it could be accomplished by simple means. The electric brake was well qualified to fulfil that condition, and the meeting had heard from Mr. Barker and Mr. King that their brakes could be so arranged. Mr. Clark, who had had great experience in railway brakes, had come to the conclusion that it was useless to attempt too much in the way of adapting the brake for all emergencies. Mr. Clark had evidently kept in view the virtue of simplicity, and his new brake was certainly a very great advance on any chain brake which he (Mr. Adams) had seen before. The system which the London and North-Western Railway Company intended to carry out in their continuous brakes was that of grouping them, instead of having all the brakes throughout a long train worked from one source of power. They considered that practical safety would be obtained if about half-a-dozen carriages were grouped together; and after very mature thought they did not regard it as necessary or desirable that for fast-running trains the brake power should be used to its full extent. In fact he gathered from conversing with their officials that they thought that for ordinary purposes the guard's brake should be mainly relied upon, and the continuous brakes used more in cases of emergency.

All the systems which had been discussed before the present meeting, appeared to provide for the brakes being applied simultaneously but not instantaneously. He should be glad to hear the views of the author of the paper as to the instantaneous application of brakes. He thought the author would hardly recommend their instantaneous application, although it was very desirable that they should act simultaneously, and with something like equal force throughout. Even in a case of emergency the instantaneous application would be very dangerous. The condition as to the slipping of carriages was not laid down definitely enough to show exactly what was meant. All the systems which had been described provided, he believed, for the slipping of a train, that was a portion being severed and put into a siding. At all events that was the case with Clark's brake and the electric brake. The "coupling of carriages indiscriminately" he took to mean that carriages might be turned either end and coupled up. That was perfectly practicable when the connection of the brakes ran through the centre, or when, as in the case of the Westinghouse brake, there were two connections.

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General CHAPIN said that the price which had been stated was certainly not intended to include the wear and tear of the brake blocks. It referred only to the motive power of the brakes.

Mr. W. ADAMS said that Clark's brake took no power out of the engine until it was required. All the brake apparatus was perfectly quiet until the moment it was to be applied. A pulley was then brought into contact with the brakes on the axle, and the momentum began to be taken from the train just at the right time. In the electric brake the only power taken from the train was what was necessary to keep the friction pulleys in motion. Of course that was very slight, and scarcely worth mentioning. The holding power was obtained by the electrical action, and the motive power from the axle of the carriage. The latter power was taken just at the moment when the momentum was to be destroyed. In the air brake and the hydraulic brake all the power to work them must come out of the engine before it was required to apply the brake. That was so much useful effect taken out of the engine. Clark's brake and the electric brake appeared to possess an advantage in that respect.

Mr. BRUDENALL CARTER, on being invited to join in the discussion, said that he felt some diffidence in so doing as he was not an engineer. It had been his business, however, to investigate the question of continuous brakes, and the first one he saw was that of Mr. Barker. Some time afterwards he saw the Westinghouse brake, and upon a more recent occasion he saw the electric brake. He was much pleased with each of them, and to make a selection he then had to push investigation farther in order to see if there were any circumstances that could in any way guide him to choose among the three. The application of continuous brakes on railway trains was the improvement which more than any other was now demanded in the interests both of passengers and of shareholders, and the question ought to be settled at once by such light as we possessed. He had come to the conclusion that the retarding power of a train as well as the motive power should be at the command of the engine driver. Those persons who were in the habit of driving vehicles knew that if they were coming upon a sharp turning they would not like the power of stopping the horses to be entrusted to a footman at the back of the carriage.

The same principle seemed to apply equally to stopping a railway train; and a careful study of the reports of the Board of Trade officials had strengthened his impression in that respect.

As one element of difference between the three brakes which he had mentioned, he found that requirement to be fulfilled only by the Westinghouse brake. He had been told that it could be fulfilled by the two others if certain things were altered; but engineers had to deal with accomplished facts rather than latent possibilities. The placing of the Westinghouse brake necessarily upon the engine was a strong point in its favour. Another favourable point was that its power was independent of train motion. It seemed a good thing that the power which stopped a train should be *ab extra*, and should not be derived, either in accumulation or application, from the train motion itself.

He found next that the three brakes—the pneumatic, hydraulic, and electric—had been in use on three railways, the Caledonian, North London, and Great Eastern, for a sufficient period of time to satisfy the authorities that they were all very good; and he therefore had evidence before him that each of those brakes, when it was in good repair and carefully attended to, would stop a train admirably. But, after all, he did not think very much of that fact, inasmuch as instead of receiving a fair trial an invention under such circumstances would really receive an unfair trial, because it would be used with greater [illegible] than would be bestowed on ordinary appliances. It would [illegible] be an object of special attention, and unless the new [illegible] was distinctly worse than the old it would be likely [illegible]. The real merit of an invention could not be dis[illegible] until it had got into the region of ordinary use, and all [illegible] concerning it had passed away. Then came the [illegible], and it seemed to him that that was a stage which, in [illegible], had not been reached in reference to any of these [illegible].

He had next considered whether he could place himself [illegible] in the hands of the inventors or their represen[illegible]. The meeting had heard from General Chapin that the [illegible] by the Westinghouse brake cost 2*s.* 6*d.* a day, [illegible] had been told by practical engineers that [illegible] was worked by waste steam which would otherwise [illegible] the atmosphere, and that the 2*s.* 6*d.* would not be [illegible] was not there. With regard to electricity he [illegible] had some distrust of it, notwithstanding what [illegible] the previous evening. No doubt electricity, [illegible] was behind it, was a very manageable force; [illegible] had tried that agent knew what happened in [illegible] they put up electric bells, and what happened [illegible] batteries when laid aside for three weeks. As [illegible] had to look at the question, "Which of these

inventions has given its proofs?" and it appeared to him that in this respect there was a great preponderance of evidence in favour of the pneumatic brake. He had heard that it had been extensively applied to all kinds of train work in the United States, where all enthusiasm as to the invention had passed away.

Mr. TOMLINSON said that, as a railway man, he took very great interest in the subject, and he believed that it was one which must be worked out. He had come to the conclusion that whatever succeeded as a continuous or "universal" brake for the railways of England must be very simple. He had had the pleasure of a journey with the Westinghouse brake, and it was certainly a very admirable contrivance for stopping a train. It, however, involved a very large expense, for it embraced certain mechanical appliances which could not be maintained for any length of time without cost. As to the electric brake, not being a good electrician he was not able to give a decided opinion, though it seemed to answer remarkably well in a trial which he witnessed on the North London Railway. It was, however, needful to consider whether such a delicate contrivance would bear the rough usage of a railway, and be ready for immediate action after standing out of use for several months, as would be the case at certain seasons of the year. The hydraulic brake certainly fulfilled its obligations in a very admirable way, but, like the Westinghouse brake, it had attached to it a certain amount of mechanical accessories which it would be expensive to maintain. It had an advantage over the Westinghouse brake, inasmuch as a very small leak in a pipe or connection of the latter would render the brake useless if the train were brought to a stand for any length of time on an incline, while in the hydraulic brake the same amount of leakage would be much longer in showing itself. It was a great advantage that there was pressure on both sides alike, as this would avoid any canting in the box or wear of the axle bar.

He now came to Clark's brake, for which his railway had been the training ground. All the schemes which that gentleman had adopted from the beginning to the end, until the last, had been tried there. Mr. Clark was now asking him to try again, and he believed that Mr. Clark's last effort was infinitely superior to all his previous ones. It had one advantage which had not yet been touched upon, and that was that it was what he (the speaker) would call a "fulcrum" brake. Some one had said that Clark's brake cost yearly 50 per cent. of the original outlay to maintain it. That seemed to be an extraordinary result which did not at all agree with his own practice. The chief expense was in brake blocks. They might put on a power

to skid the wheels, and so save the blocks, but it would be at the expense of the rails and tires; and it was better to pay for blocks than for tires. His railway was the only one which had yet managed to wear out a steel rail. The life of a steel rail of a $1\frac{1}{8}$th-inch head was only about two years. He could produce one which had worn down to $\frac{3}{8}$ths of an inch. That was the effect of skidding the wheels. They wanted a brake which would affect every wheel of the train without picking up the wheel. If they could only retard the train in that manner they would have arrived at the desideratum. His own experience was that if the train had anything like speed on, and the wheels were skidded, there was no brake at all. He had found in going down an incline on the Taff Vale line that upon applying as many brakes as possible and skidding the wheels, the wheels were picked up and the speed of the train began to increase. He then opened the regulator, and gave the engine power to grind the brakes. The wheels were then just able to bite and hold the rail. That was a proof that a skidded wheel was not so effective in retarding a train as a wheel slightly revolving.

Mr. CLARK said that General Chapin in drawing a parallel between his own brake and that invented by him (Mr. Clark), had made the mistake of selecting that form of the latter which had recently been superseded. In justice to the subject General Chapin ought to have confined himself to the brake which had been described in the paper, and which had shown very favourable results. That brake secured the advantage to which Mr. Tomlinson had alluded in speaking of a fulcrum brake. Every part of the chain was equally tight, and pressed all the blocks equally, and the whole was applied by the tension of one chain. As the power was regulated by a weight it might be much or little, as desired.

Mr. GEORGE ALLEN said that in the case of any system of brakes which depended upon friction there must necessarily be a great deteriorating element at work if dirt of any kind penetrated. Mr. Robertson, the inventor of frictional gearing, after many years' experience had found it necessary to abandon it. He had found that there was nothing so uncertain in practice, though it was a very beautiful theory. Every time it was in operation it was deteriorating; and when such gearing was under the bottom of a railway carriage no one could know what would arise to interfere with its effective action. Sand and other substances would insinuate themselves, and so grind the surfaces as to cause excessive wear. The electric brake in that particular was essentially a frictional brake. No matter how effective the electricity might be as a motive power, the means by which the brake was put into operation were defective.

Clark's brake and even the hydraulic brake were superior to the electric in that respect. Moreover, although the electric brake had been some eight years before the public, it had not progressed in public favour, and he believed the reason was that there were no means of regulating its force. General Chapin's invention had for its object the graduation of the power, that being absent from the original brake; but even with that improvement the brake contained elements which were altogether inconsistent with the diminution of wear and tear as compared with other brakes.

The working of brakes in the United States by means of a rope or chain had been carried out more effectively than in this country. Here, certainly, it had been a dead failure. In this country we had tried to do too much with the cord; but even in America the electric brake, whatever its merits, had not been appreciated by railway engineers. If there were any merits in it to justify its use, its adoption by American engineers would assuredly have followed. Again, the attempt to pull up a train by the instantaneous action of the brakes was a mistake. Engineers knew very well the effect of the sudden stoppage of any piece of machinery, and they could judge of its effect upon a train going at, say, 60 miles an hour. With the exception of the Westinghouse brake, all the brakes he was acquainted with were of an inflexible character, that was to say, they had no means of cushioning themselves, or of taking up the resistance in a gentle manner. Mr. Adams had said that he did not quite see how the elastic medium in the air brake, not being applied directly to the brake blocks, could possibly soften or cushion the pressure. It was clear, however, that if the cushion was applied at the end of the lever, it must be just as effective as if it was applied on the brake block. The resistance or strain must be taken up somewhere, and in the case of the Westinghouse brake the strain delivered itself in the air cylinder under the carriage. In no case was that feature brought out in the other brakes, although it effected a saving both in the wear of the vehicle and in that of the brake. The cost of the electric brake was stated as 4½*d.* per day for battery power. That was certainly a low cost, but the brake was a frictional one, and frictional surfaces had proved a failure in this country because of the cost of maintaining them; and hence in the course of a few years the cost of the electric brake would become excessive, and too great to justify the adoption of the brake even in every alternate carriage. Besides the wear and tear of the frictional surfaces, there were journals and bearings to be oiled. It had been said that the Westinghouse brake cost 2*s.* 6*d.* a day. He believed, however, that that was a fallacy, and that a great

number of engineers who were using it could be produced who would say that the cost was nothing. The test was not the quantity of steam used by the brake, but the additional quantity of coal served out in consequence of the brake. No man who had had the Westinghouse brake under his control had been under the necessity of calling for additional fuel. In fact if the question came to be investigated it might probably be found that the brake caused an economy of the fuel. It enabled a train to be run up to its speed into a station, and then stopped with great certainty, the surplus steam being used for the air pump of the brake instead of being blown off. At the same time, the stoppages did not require to be so gradual, and in consequence time could be saved on the journey. It was a fact that upon a line of 148 miles the introduction of the Westinghouse brake saved twenty minutes of time on the journey. Such a saving of time meant also a saving of fuel.

He agreed with the opinion that wheels which were just permitted to revolve must be more effective in their brake action than skidded wheels. In any inflexible brake system there was always the risk of skidding. The air brake was therefore the only brake independent of that tendency. He had been told that on two occasions complaints had been made by the passengers as to the vibration produced by the hydraulic brake. That effect might not be due to a fault of the brake itself, but to the want of considerateness on the part of the driver in putting it on. But still the possibility of such an effect was certainly not in favour of the brake.

Mr. MACKIE said that it had been stated that the Westinghouse brake used steam which otherwise would be blown off every time the engine came into a station. His experience as a passenger on the Metropolitan Railway was that the engines, after having condensed from the Mansion House to King's Cross, came very much short of their blowing-off pressure. It therefore appeared to him that on that line at least the cost of steam had to be taken into consideration.

Mr. BARKER then read the following remarks: Having been present during the previous discussions on this important subject, I have noted down some facts in connection therewith, based upon my own experience. In the first place with regard to the skidding of the wheels the letter read by Mr. Spencer is most interesting, but, notwithstanding that it comes from so high an authority as Mr. Fay, it appears an anomaly. I think it will be generally allowed that supposing the wheels did give a higher percentage of retarding power just revolving, yet taking into account the exceedingly varying character of the adhesion of the wheels on the rails, in a case of emergency the only safe and wise plan is to stop the wheels immediately.

If the adhesion of wheel and rails was constant, and it was really found that the maximum retarding power was just below the skidding point, then I should say by all means regulate the brakes so that no more power might be applied. If this is good for continuous brakes it will be the same for hand brakes, and the power a man can apply should be regulated accordingly. But it is not so, the adhesion varies from ·089 to ·268; if a man could only apply just enough power with a hand brake to allow the wheels to rotate it would be a very inefficient one in practice, and it will always be found that the argument in favour of the wheel just revolving is always put forward when there has been a want of power and a difficulty in obtaining sufficient to ensure the picking up the wheels in all weather.

Another point raised was the corrosion of the metal tubes through the employment of a saline fluid. It is unnecessary for me to say anything with regard to this, as Mr. Johnson has stated that the pipes show no sign of corrosion. There has been some question as to the degree of frost that would disable the hydraulic brake; there ought to be none, owing to the simple fact that a saturated solution of common salt does not freeze until zero Fahrenheit is reached. Chloride of calcium and water will not freeze until 20° Fahrenheit below zero is reached. As regards cost, the hydraulic brake consumes a gallon of water per day per train, and with salt it costs, say, 2*d.* per day. Chloride of calcium I should employ only in colder climates than England.

Mr. Pendred, after stating the favourable results he had witnessed with the hydraulic brake on the Great Eastern Railway, said that an accumulator capacious enough to work a train of ordinary length would have to be very large. This is not so, as in the Loughton train of twelve carriages the accumulator occupies less space than that in the Victoria Park train. Another point was the speed of the pump; the pump is specially constructed to resist such high speeds, and two years' working show no evil arising therefrom with trains so fitted. This is not a necessary part of the hydraulic brake, as a steam donkey-pump if the accumulator is fixed on the engine would enable it to be dispensed with.

The following statistics respecting the working of the hydraulic brake may perhaps be interesting: The Hackney Wick train, working 500 days, made 128,000 stoppages, and travelled 50,000 miles. The Loughton train, working ten months, made 20,000 stoppages, and has run 30,000 miles. An experiment was made with the Hackney Wick train, which, when running at 55 miles per hour was stopped in 153 yards; the wheels were purposely all instantly skidded. According to the theory of

allowing the wheels to slightly revolve, the train ought to have stopped in a length of 100 yards, which I do not believe is possible. Next with regard to maintenance, which is stated to be 2*s.* 6*d.* per day for the atmospheric, and 4½*d.* per day for the electric, brake. According to this mode of calculating, taking the cost of water, salt, oil, &c., I find the hydraulic will not cost more than 1*d.* per day, not that I attach much importance to this, since I believe where one brake has been shown to be cheaper than another, the additional renewals of tires ought to be taken into account, as the brake which permits of the quickest stoppages with the least injury to the tires, framing, axle, guards, and rolling stock generally, will quickly prove itself the most economical and will be most favourably received by railway engineers, provided that it can also be relied upon in action, which is of the first and main importance. A continuous brake ought to be considerably less liable to fail than the engine, since its failure might lead to much more serious consequences than that of an engine. If reliable the amount of saving, directly and indirectly, as regards maintenance, time, and absence of damages, will quickly repay the outlay for the brake.

Hitherto I have had as an attendant a guard on the Great Eastern Railway, who has been responsible to me while the brake was going through the experimental stage. When the company take over the five trains, which are now being fitted up, a man will be appointed by the company to take charge of them. All continuous brakes must undoubtedly be properly inspected and more carefully watched than an ordinary brake. If a hand brake fails it is not of much importance, but if a continuous brake is out of order, the result may at the least lead to great inconvenience.

With regard to Clark's latest design and Naylor's brake, in both these the amount of force on the brake cannot be regulated, nor can the brake be put on hard or soft according to the requirements of the case. This is not a correct principle and would not be tolerated with the hand brake. The objection to the blocks being applied on both sides might hold good if the blocks were held together by a rigid rod. But they are at liberty to move out and in as they are with the hydraulic brake, and allow the springs to act and at the same time prevent the axle being forced out of the journal, and the axle box against the axle guard. This liberty of the axle boxes to play would be still further improved by hanging the blocks on a centre like the cast-iron blocks, when, I believe, the action as regards the springs would be, for all practical purposes, with the hanging flap brake as perfect as the slide brake when the bar is fixed to the axle box.

The first requirement of a perfect brake, I would submit, is that its rapid instantaneous application should bring no sudden strains on the framing or axle guards. The second is that the pressure should be balanced so as not to affect the journals or axle guards. The third, that the application of the pressure should be capable of even nicer adjustment than the hand brake. The fourth, that there should be the least possible weight under each carriage, and I contend that the hydraulic system fulfils all these conditions perfectly. I am about fitting up one of the Great Eastern Railway tank engines with the hydraulic brake, and an exceedingly simple arrangement will give me all the power I require. A steam donkey-pump will store up the force necessary to give the same mechanical effect or apply the brakes with the same degree of force where water is the medium and with less expenditure of steam, consequently with less expense for fuel than where air is employed to transmit the power.

Mr. Fox then read the following reply: In replying upon the numerous points that have been raised during the discussions I feel that I have a somewhat onerous duty before me, but I shall endeavour to discharge that duty to the best of my ability, and I trust to the satisfaction of those to whom I have to reply.

The first remarks I have to deal with are those made by Mr. Spencer, who stated that I did not describe Mr. Clark's brake fully. The drawings and descriptions of the various brakes laid before the Society were all submitted to the respective inventors. Mr. Clark stated at the time that the arrangement shown was the simplest and best that he had brought out. Mr. Spencer next referred to skidding the wheels, stating that it was a question with engineers as to whether a train could be stopped more quickly by allowing the wheels to revolve during the whole time the retarding power was being applied or not. He read a letter from Mr. Fay, giving the results of two experiments on the subject. In one, the train with all the wheels skidded was stopped in 400 yards, when moving at a velocity of 60 miles an hour; the other indicated that it could be stopped in 240 yards if the wheels were allowed to keep revolving while the retarding power was being applied. In the absence of further experiment I agree with Colonel Yolland on this point, because it is necessary for the maximum amount of force to be applied to skid the wheels, therefore it is only fair to assume there must be more resistance thrown out to the motion of the
an if the wheels were allowed to continue revolving
's being brought to a stop.
rker stated that he did not consider my coefficient of

friction for wood blocks in dry weather high enough. I admit that I stated the coefficient rather under the mark, preferring to err a little on the right side. In the experiments recorded in Table D, the coefficient in one instance only reached as high as ·40. The question, however, is one which requires further attention. Mr. Barker next refers to the conditions the hydraulic brake complies with, and states he meets the requirements of the first absolutely. I would merely mention that Mr. Barker is about fitting his apparatus complete in every respect on an engine of the Great Eastern Railway. To answer the rest of his remarks as to fulfilling the conditions would be merely to repeat what I have already said in my description of this brake. One point, however, deserves notice, and that is that the inventor has applied an air vessel to steady the hand of the pressure gauge, which vibrated very considerably, and it has been found incidentally to improve the easy working of the brake.

The next remarks for consideration are those on the Westinghouse brake, which were made by Mr. King, who stated that a reservoir placed at the rear end of the train would arrange for applying the brakes automatically, and also allow the guard to apply them from that end if necessary. With this I cannot agree. A reservoir placed at the rear end of the train would not afford automatic action unless an arrangement was also provided for allowing the compressed air to escape into the cylinders when the train parted. To keep the reservoir always charged with air by the apparatus on the engine would probably be a continual source of trouble; while a fatal objection would be raised to this proposition if carriages were required to be added or detached during the journey. The next statement made by Mr. King calling for remark is with reference to loss of time in getting the whole of the brakes into action. On this point I can see no reason to change my opinion that an average loss of two seconds would take place in applying the whole of the brakes to a train of engine, tender, and ten carriages, as stated. The observations made by Mr. King were on a short train requiring but about one-half the quantity of air to apply the blocks as in the case mentioned by me. Again, as air is highly elastic it does not follow that immediately the blocks move on to the wheels at the far end of the train the full pressure is applied throughout, as in the case of the hydraulic brake; because when the expansion of the air has taken place to the extent of giving only 5 lbs. pressure in the last cylinder the blocks would move on to the wheels. In fact, to say that a fraction of a second is all the time necessary to apply the full amount of retarding power in the case investigated

by me would be to set aside all the elaborate experiments of Poncelet, Napier, and Wilson, and to establish a new and entirely different law for the efflux of elastic fluids.

I now come to the remarks made by General Chapin as to the efficiency of the electro-magnetic brake; he first stated that the local batteries provided for slipping the carriages, and also claimed that the local batteries acted automatically if the train parted at any portion of its length. It therefore follows that, without some special arrangement, if one or more carriages were slipped the local batteries would be applied and both parts of the train stopped, whereas what is required to be done is to slip the carriages and allow the leading portion of the train to complete the journey without hindrance. I believe, however, that General Chapin would have but little difficulty in complying with this condition. General Chapin next stated that the arrangement of gear shown in his new plan would cause the whole of the blocks always to press on the wheels with practically the same force. This, however, cannot be the case, for the fulcrum of the lever under the carriages being a fixed point, and as the rods which draw on the brake blocks are connected to the lever at equal distance from the fulcrum, it follows that the travel of the blocks must always be exactly the same. Therefore if the blocks wear unequally the pressure will sometimes be on one pair of outside blocks only.

The snap given to the chain cannot be overcome. During the recent snowy weather I heard it stated at Bow that five or six chains working Clark's brake had broken in one day on the North London Railway. With respect to the locomotive clutch, this objection was pointed out to Mr. Sykes before the paper was read, and I asked him if he had any arrangement for meeting the difficulty, but as none was produced the objection was necessarily retained. I will, however, point out a probable objection to its being applied to the engine. Assuming there is sufficient space at the back of the fire box to place the clutch apparatus, and to obtain as much leverage as in the case of the carriages, now as the locomotive is taken at three times the weight of a carriage, it follows that the magnetic clutch must give out three times the retarding force, so that instead of having a strain of only 1 ton on the axle, there would be one of 3 tons on the trailing axle of the engine: an objection which requires no comment.

As to the force required to move the armatures on the friction plates varying with different clutches owing to two different size wires being used, I would merely remark that the size of the wire and its weight were given by Mr. Sykes, the electrician, who also assured me that the experiments were perfectly fair

in every respect. On pointing out the objection raised in the paper, Mr. Sykes did not mention that two kinds of wire had been used. A slight consideration of the question will show that three things at least must take place, so that the friction and armature plates shall resist rubbing on one another to the same extent.

1st. The attractive power of the magnets must be the same.

2nd. The quality of the metal plates must be exactly the same; and

3rd. The plates must have the same surfaces and wear exactly alike.

Remembering how the plates were cut on their surfaces, and Mr. Sykes's statement as to the fairness of the experiments, I cannot but believe that the differences stated in the paper were not due so much to the wires as to a practical defect which there will be some difficulty in remedying.

General Chapin next referred to the reduction in thickness of the friction plates and armatures. I can only repeat the statement made in my paper, that the plates when first measured were $\frac{1}{2}$ inch thick, but now are only $\frac{3}{8}$ths. On examining them to take the second measurement I pointed out to Mr. Sykes the quantity of iron dust around the clutch, showing the wear of the plates and axles. General Chapin then goes on to say that the diameters of the axles had been reduced in turning them true for the friction rollers. When I took measurements and sketches of the arrangement I noted that the axle had been turned true for the friction roller, but the reduction was very slight, certainly not more than one-third what it now is. I have already said that the apparatus when applied must either skid the wheels or cause the armatures and friction plates, and also the axles and friction rollers, to rub on one another with great force, and it is not possible for them to do so without considerable wear.

With reference to a remark made by Colonel Yolland as to the guard being able to apply the brakes as well as the driver, I will merely quote Condition 3, which states "that it is necessary that the brake apparatus be capable of being applied from the trail end of the train as well as from the engine." Colonel Yolland also stated that tender engines should be provided with efficient brake power. The importance of this is strikingly shown by a series of experiments made by Sir William Fairbairn for the purpose of testing the relative efficiency of Messrs. Fay and Newall's brakes. The experiments were published in the 'Transactions of the Institution of Civil Engineers for 1859.' On referring to Tables A and B it will be seen that the theoretical Tables given in my first paper are verified in

practice; and also if the stops recorded in Table A with the engine detached be compared with those in which it was attached, but without any brake, it will be seen they were made in the inverse ratio of the weight of the train. Take, for instance, the stop made with Mr. Newall's brake with engine detached, experiment No. 2, speed, 32·72 miles per hour, distance of pulling up, 56⅜ yards, and compare it with No. 1, Table B, engine attached, speed, 33·96 miles per hour, and distance stopped in, 125 yards. In the first instance it will be seen that the maximum retarding power is applied to the whole weight of the train, while in the second it is only applied to 37½ tons out of 61½ tons; so that the stop, supposing the velocities to have been the same in both cases, would be made as 37½ : 67½ :: 57 yards : 103 yards. To this will have to be added the distance due to the slight difference in the two velocities, which will increase it as $(32{\cdot}72)^2 : (33{\cdot}96)^2$, or as 107 : 115 .·. 107 : 115 :: 103 yards : 110 yards, instead of the 125 yards given in the experiment. This slight difference may be due to the guard and driver not applying the train and tender brakes in the latter experiment exactly at the same time. Therefore if we wish to stop a train in the least possible distance, we must exert the maximum amount of useful retarding force to the engine, tender, and every carriage comprising it, and in proportion to the weight of each, as stated in Condition 4.

I believe many locomotive engineers object to putting brakes on the engine on account of the jar given to the machinery and the wearing of flat places in the tyres from skidding the wheels. I would submit, however, that with efficient continuous brakes these objections are got rid of; because there is a great difference between them and those which are applied to the engine, tender, and brake vans only. In the latter, to make a quick ordinary stop, all the wheels must be skidded as the retarding power is concentrated; but in the former, to make a stop in the same distance the same amount of retarding power may be distributed over the whole train, and therefore skidding of the wheels is avoided.

Mr. Mackie stated that the Electric brake was the only one that complied with Condition No. 2; and that in my summaries of the Hydraulic and Atmospheric brakes I set aside my condition because I stated that those brakes might be efficiently applied to a train of reasonable length. There is nothing in Condition No. 2 that would lead anyone to suppose I mean a train of an unreasonable length. Again, the condition states that the brakes on each carriage of the train shall be capable of being efficiently applied by the driver whatever its distance from the engine, *i.e.* the driver must have the same

command over the brake at the trail end of the train as he has over the one next the engine, and not, as in Mr. Clark's brake, where the farther from the engine or van from which it is applied, the less efficient the brakes are. Mr. Mackie states that all the brakes fulfil the first part of Condition No. 4, and that the electric is the only one which fulfils what he calls the second part. To my mind the electric brake does not fulfil the condition in either case completely; and if it was made to do so there would probably be, as I have already stated, at least 3 tons placed on the trailing axle of the locomotive when the brakes were fully applied. Mr. Mackie says Condition No. 6 is only fulfilled by the electric brake on account of the liability of the air-brake cylinders and reservoir to burst. He complains that I only refer to the pipes being in duplicate, as though the apparatus consisted of air pipes alone, and that I mention nothing about the reservoir bursting. Now the batteries and wires of the electric brake are as liable to accident, and at least to get out of order, as the reservoir to burst, the probability of which is very remote indeed.

Mr. Mackie states that Condition No. 7 is an impossibility, and that I must have meant simultaneously for instantaneously; that even if it were possible it would be a great disadvantage, as a large amount of power would be lost because the sudden application of the brake blocks would skid the wheels, and that the electric brake applies the blocks practically simultaneously, and has also the advantage of applying them gradually. I would ask where is the practical limit as to how quickly the blocks can be applied to the wheels between instantaneously and two seconds? In the cases of air and water the time will vary from one to two seconds in a train of ten or twelve carriages, according as the blocks are worn. In the case of the electric brake we have it reduced to a maximum of two-thirds of a second, and a minimum of about one-third of a second even in its (to use Mr. Mackie's words) present crude state. I think, however, that the supporters of the electro-magnetic brake should hardly say it is impossible to apply the retarding power throughout the train instantaneously, because that is the strong point of the invention, as will be clear when we consider the great forces that can be exerted instantaneously by means of electro-magnetism at considerable distances apart. But I do not mean simultaneously for instantaneously, because it does not express all that is necessary; for we not only require in a case of emergency the retarding power applied to the engine, tender, and all the carriages at the same moment, but we want it applied in the least possible time also. Simultaneously only expresses half the condition, for we may occupy two, four,

or six seconds, and still comply with it. Mr. Mackie next states that it would be a great disadvantage to apply the retarding power instantaneously, because the wheels would be skidded by the sudden application of the brake blocks; and that the electric brake can apply the power gradually. It seems to me that if the driver can regulate his brake power properly—which the condition requires—the case is met most fully.

Mr. Mackie asks the meaning of Condition No. 9, stating that it ought to mean that carriages not fitted with continuous brake apparatus should be capable of being coupled to a train without interfering with those that are. This condition must be understood by the light of the paper, because considered irrespectively of my views with reference to the application of brake power, it will appear vague. My opinion is, and my paper is based upon it, that it should not be lawful for any vehicle to run on a railway without being fitted with efficient brake apparatus, and that when those vehicles are coupled together the driver and guard shall be capable of applying the whole of the brakes. What I mean is that whichever kind of vehicle may be required, and whichever end of it may be presented for coupling, no inconvenience shall arise.

With regard to Condition No. 10, Mr. Mackie says I should have stated my views of complicated parts. I could not do more than define the parts which appear to me complicated, as, for instance, in the hydraulic brake, that the arrangement in the van was complicated, while that underneath the carriages was extremely simple. Referring to Condition No. 12, Mr. Mackie states he should have left out the latter part of this condition; and that the hydraulic brake is the only one that complies with it. I will explain my reason for the second part of this condition. If we wish to put a ton pressure on a brake block for the purpose of stopping the revolution of a wheel, the effect will be the same as regards stopping it, whether it be done through the medium of air, water, or hand power and levers; therefore some hold that, if the effect to stop the wheel is the same in each case, there is no advantage in using an elastic medium in preference to a rigid one. But we must not only consider the effect we have on the wheel, but also the effect the resistances of the wheel will have on the applied power and the mechanical arrangement through which the retarding force is exerted, as well as on the passengers. I therefore hold that the pressure should be applied to the blocks through an elastic medium. Vibration is due to one of two causes; either to the irregularities of the tires and blocks when the wheels are revolving with the retarding power applied, or to irregularities in the rails when the wheels are skidded. The

first may be considered to give it in partly vertical and partly horizontal lines; while the latter may be considered to do so directly in vertical lines only. Now it is evident that if the blocks are rigidly pressed on each side of the wheel the vertical forces due to the irregularities will be communicated through the brake hangers to the carriages, while the horizontal ones will be spent on the brake apparatus. If, however, you press the blocks on with an elastic medium, you allow the wheel to slip between the blocks and play on springs whatever may be the direction of the vibrating forces. Mr. Mackie states that the hydraulic brake is the only one that complies with this condition, because the water in the cylinders is in direct communication with the accumulator springs; the reason is, the water has to pass through a regulator after leaving the accumulator. Of the atmospheric brake, Mr. Mackie says we have 50 lbs. on the square inch in the cylinders at a considerable leverage. For making ordinary stops only about half that pressure in the cylinders is necessary, so that the pressure on the horn plate is reduced to about 1 ton; but Mr. Mackie appears to forget that this one ton on the horn plate arises from not having the blocks on both sides of the wheels—a fault that belongs at present to the electric brake as well as to the air brake, and which has been pointed out in each case in considering how far these brakes comply with the conditions.

I cannot agree with Captain Fairholme and Mr. Adams, that it is not necessary to apply the brakes to every carriage. George Stephenson, when examined before the select committee on railways, in 1841, said, "I believe that if self-acting brakes were put upon every carriage scarcely any accident could take place." If it is better to apply the brakes to four carriages in a train of ten than to only two, and also better to apply them to six than to four, it follows that it must be a greater advantage still to apply them to the ten than to the six only. Another objection to Captain Fairholme's proposition of placing brake apparatus on a certain number of carriages only, and in certain portions of the train, is the probable inconvenience that would arise in making up a train and adding or detaching carriages on a journey, because they could not be taken indiscriminately. I will admit, however, that if efficient brake power be applied to the engine, tender, and five carriages out of a train of ten carriages, it is at least as good if not better than applying it to all the carriages only; because the same amount of retarding power is better distributed throughout the train. On the other hand, if it is applied to the whole of the train, including the engine and te[illegible]s may be done by the air and hydraulic brakes, then

the train will be stopped in a better manner and in less distance than in either of the other cases.

The remarks made by Mr. Johnson with reference to the two brakes he has had special experience with on the Great Eastern Railway will be endorsed, I think, by all who have given the subject the least attention.

With regard to Mr. Pendred's remarks as to whether we are really doing the best thing in applying the retarding power to the wheels by means of blocks, I will merely state that it certainly does seem that we are a long way from perfection when we consider that the coefficient representing the work done is only $\frac{1}{4}$th or $\frac{1}{5}$th of that actually put upon the block. It will be remembered that a retarding force equal to 18 per cent. of the weight of the train was shown to be sufficient in ordinary weather to stop it in 220 yards, but to obtain this 18 per cent. by means of brake blocks we are sometimes obliged to apply 90 per cent. of the weight of the train.

I hope Mr. Varley does not suppose that I consider electricity unsuitable as a means of obtaining efficient brake power. My objections to the electric brake refer to the mechanism by which it is at present applied, and also to the probable cost of maintenance. That the electric brake when perfected will have many great advantages I admit, and among the most important of them will be that each carriage will be complete in itself. But the electric brake on the North London Railway and the electric brake of the future will, I am persuaded, be as different from one another as Stephenson's "Rocket" was from the modern locomotive engine.

Mr. Clark introduced to the notice of the members a new and improved arrangement of his brake. It is not my intention to criticise it, because it has been brought out since the reading of my paper on the chain brake. I will only say that it appears to be extremely simple.

The information given by Mr. Halpin and Mr. Tomlinson, as to the advantage gained by not skidding the wheels, is perhaps the most important part of the discussion. If we compare it with the instance quoted by Mr. Spencer, we shall find them agree very nearly. But when we consider the experiments made by Sir William Fairbairn with Messrs. Newall and Fay's brakes, we shall feel the question is still a doubtful one. Compare, for instance, Experiment No. 10 (Table A) with Mr. Fay's brake; in this instance we have the train when moving at a velocity of 60 miles an hour stopped in the short distance of 204 yards by skidding the wheels. It follows then—supposing Mr. Spencer's and Mr. Halpin's data to be correct—that the

train could be stopped with the wheels revolving in a distance of $\frac{\cdot 128 \times 204}{\cdot 192} = 136$ yards.

I do not think the experience of any engineer leads him to believe that this can be done under the above conditions. With reference to Mr. Halpin's remarks as to Mr. Naylor's brake, I may state that previously to writing my paper I made inquiries of Mr. Martley, the locomotive superintendent of the London, Chatham, and Dover Railway, as to the success of that brake, and was informed that Mr. Naylor, through ill health, had not been able to perfect his invention, and that consequently it had been abandoned. Under the circumstances therefore I thought it best not to describe it in my paper.

I have next to reply to several objections raised by Mr. Bernays to Conditions 1, 2, 10, and 11. The objection to Condition 1 has already been answered by General Chapin. I would remark, however, that it appears to me that the operation of simply moving the key in the electric brake or turning the cock in the air brake is more expeditious and involves less labour on the engine than having to apply the ordinary tender brake and whistle to the guard as now done. Considering this and the great advantage gained by placing the retarding power in the hand of the man who is most likely to first observe danger, I am unable to coincide with Mr. Bernays that the word "advisable" should be substituted for "necessary." Condition 2 has also been explained in accordance with my views, by General Chapin. In my paper I state that 220 yards is the least distance that should be reckoned we could stop a train moving at a velocity of 60 miles an hour by skidding the wheels in ordinary weather, and I advocate that sufficient retarding power should be provided for doing this. Table A (in my first paper) is given to show the advantage of this, by pointing out the relative distances the same power would stop a train at various velocities. In turning curves in cuttings the power of stopping a train moving at 30 miles an hour in 60 yards instead of 220, as advocated by Mr. Bernays, must certainly be reckoned a great advantage; while on very foggy nights it would be found useful in stopping at stations. Mr. Bernays' proposal to add to Condition 10—"And if out of order the defect shall be easily detected and easily remedied"—I accept as an improvement on the original.

With reference to Condition 11, I admit that Mr. Bernays' objection is a perfectly valid one, if the blocks are hung from the framing of the carriage in the usual manner, and if they are forced on the wheel by a rigid instead of an elastic medium; but I cannot agree with his proposal to reverse the condition.

First, let us consider the advantages and disadvantages of applying the blocks on one side of the wheel only, as shown, for instance, in Drawing No. 5 (Electric Brake); and let us take $1\frac{1}{2}$ ton as the force exerted on each block without skidding the wheels, for I strongly object to skidding the wheels for ordinary stops. This force of $1\frac{1}{2}$ ton on each wheel will tend to bring them together, and raise the longitudinals of the carriage in the centre. This condition of the longitudinals is likely to increase vibration, while in itself it is often felt and complained of by railway travellers. Then, again, the bearings wear unequally the whole time the train is being stopped, and unnecessary strain is thrown upon the axle guard. On the other hand, as stated by Mr. Bernays, it comparatively interferes but little with the action of the carriage springs.

By applying the blocks to both sides of the wheel, we at once get rid of the whole of the disadvantages attending their application to one side of the wheel only; it therefore only remains for me to consider how the action of the springs is interfered with, and how the interference may be obviated. If the blocks are made to hold the wheel by means of a rigid medium, such as water, without a cushion of air or other means for producing elasticity, the wheel, blocks, and carriage become one, and the carriage springs practically useless; so that all the vibrations or vertical forces arising from irregularities of the rail, if the wheels be skidded, or from inequalities or indents in the tyres when the wheels are revolving, are communicated through the block hangers to the carriages and passengers. As that portion of the wheel above its diameter and between the blocks may be considered as a wedge, it follows that any effort of the wheel to rise must tend to drive the blocks farther apart, and consequently communicate vibrations by means of the water in the cylinders and pipes to the pressure gauge in the guard's van. Now it was owing to observing the intense vibrations of the pressure gauge of the hydraulic brake that I was led to conceive that an elastic medium should be used; because it follows that, if the cylinders and pipes contained air, the blocks would be allowed to yield the very slight distance required to permit the wheel to slip, and the carriage springs to come into play. The blocks should be carried in such manner as to permit them to fit the wheel accurately, however loaded or otherwise the carriage may be. An objection may be raised to this proposition, because, when ascending or descending an incline, the tendency of the blocks to maintain a vertical position would perhaps cause them to touch the wheels; but little difficulty would be met with in overcoming this objection. The blocks should be hung from a common centre over the wheel.

Referring to Mr. Clark's remarks, I cannot think the proposal of the North-Western Railway Company to divide the brake power for long trains into several sections a desirable plan, because they are not likely to act simultaneously; and in a case of emergency it is extremely doubtful whether half the brake power would be got into action in time to be of much service. In fact, the arrangement is a further application of the very questionable plan of having one kind of brake for the engine and another for the carriages.

A most important question has been entirely overlooked in the discussion, *viz.:* What is the best material for brake blocks? For reasons already stated I believe that metal blocks are superior to wood; and in support of that opinion I will read copies of two letters written to Captain Fairholme, one signed by the Locomotive Superintendent of the Royal Prussian Upper Silesian Railway, and the other by a Director of the Right Bank of the Oder Railway, as to the superiority of a mixture of cast iron and cast steel for brake blocks.

SIR, BRESLAU, 2*nd December*, 1872.

In reply to the application made by you to the Board of Direction of this railway, which has been referred to me, I have the pleasure to inform you that out of the 345 sets of your cast-steel brake blocks, which have been gradually introduced into use on different carriages on this railway since the month of April, 1867, only eight sets, which have been in use on passenger train guards' vans, are actually completely used up, each of them, however, having been employed on an average distance of 32,213 German miles (144,758 English). Not less advantageous does the result with the remaining sets in use on other carriages promise to be, as, notwithstanding that each of them has already on the average been employed on a distance of about 10,000 German miles (45,000 English), they all appear to promise an endurance fully equal to those above mentioned as being completely used, the expense of which by each mile of distance being calculated as having been 0·0674 of a pfenning.*

(Signed) GRIMMER,
Locomotive Superintendent of the Royal Prussian Upper Silesian Railway.

SIR, BRESLAU, 3*rd January*, 1873.

In reply to your letter of the 14th ultimo, we have the pleasure to inform you that according to the report of our locomotive superintendent, the application of your cast-steel brake blocks has been attended with most satisfactory results as well on goods wagons or guards' vans, as also on engine tenders. The brake power developed is sufficient, and skidding the wheels can only be produced by the greatest exertions of the brakesman, in consequence of which the wheel tires are beyond all comparison more saved than by the use of wooden blocks.

The saving of the wheel tires (which are considerably less, and at the same time more regularly, used up) and the saving in rails resulting from this form

* This would amount to only 15*s.* 0¾*d.* per brake blocks for one carriage in 150,000 miles of distance.

most important advantages in these brake blocks. The expense of fitting and maintenance are also, in consequence of their great endurance, less than those with wooden blocks. No case has as yet occurred of a brake block breaking, while the same can be said of the wheel tires on which they have been used. In consequence of these favourable results we have decided on a further application of your cast-steel brake blocks, and have consequently inserted them as one of the stipulations in our contracts for the purchase of all new goods wagons.

(Signed) GIHME,
Director of the Right Bank of the Oder Railway.

In conclusion, I would observe that it matters not whether we consider the simple arrangement designed by Mr. Clark; the efficient regulator of Mr. Barker; the ingenious coupling and close attention to minutest details displayed in the air brake; or the simple means by which retarding power may be made to act almost instantaneously throughout a train of any length by the electrical brake, we find abundance of thought and skill displayed. From what I have seen I am sure there are few who can fully estimate the expense and anxious labour incurred by each of these inventors in respect of their continuous brakes, with either of which, with 200 yards of warning, railway collisions ought hereafter to be an impossibility. It only remains to prove which is the cheapest, best, and most reliable. It was for this and for the purpose of obtaining justice for the inventors and the public that I suggest that exact trials should at once be commenced by several of our large railway companies. If it had been a question of guns instead of brakes, it would have been taken up by the Government long ago; for it is remarkable what an enormous amount of money is spent annually at Shoeburyness, Chatham, Woolwich, and other naval and military establishments, for the purpose of testing by exact experiment which war engine will deal out most destruction to human life, as compared with the little that is expended in its preservation, either with reference to reducing mortality by enforcing improved sanitary arrangements, or by ensuring the safety of railway travellers or those who go down to the sea in ships.

The PRESIDENT said he considered the Society was greatly indebted to Mr. Fox for his able papers. They were of an eminently practical character, and related to a subject which was prominently under consideration by the profession at the present time. Mr. Fox had laid down certain conditions which had been, with but very slight amendment, admitted to be correct. He (the President) would like to have heard the question of the cost of maintenance in the various brakes elucidated a little more. The members had not had sufficient evidence before them to enable them to judge of the merits of

the various inventions with respect to the cost of maintenance. In railway matters that was a subject of very serious consideration. There could be no doubt that railway men would give the preference to that invention which was most reasonable in its first cost and most economical in maintenance.

APPENDIX.

The following Tables appeared in the author's previous paper, and are here reproduced for reference with the foregoing paper.

TABLE A.

TABLE showing DISTANCE travelled by a MOVING TRAIN on the LEVEL at Velocities of 20, 30, 40, 50, and 60 miles per hour after shutting off Steam, and applying —by means of continuous brakes—a retarding force equal to 18 per cent. of the weight of the Train.

Speed per hour in miles.	Speed per second in feet.	Distance travelled after Steam is shut off, in feet.	Distance travelled after Steam is shut off, in yards.	Time required to stop Train, in seconds.
20	29⅓	73⅓	24⅓	5
30	44	165	55	7½
40	58⅔	293⅓	98	10
50	73⅓	460	153	12½
60	88	660	220	15

TABLE B.

TABLE showing PRESSURE to be APPLIED in LBS. to BRAKE BLOCKS for COEFFICIENTS of FRICTION varying from ·15 to ·35, so as to give a retarding force to each wheel of a carriage weighing 10 tons, sufficient to stop it in 220 yards when moving at Velocities of 20, 30, 40, 45, 50, 55, and 60 miles per hour.

Velocity in miles per hour.	Velocity in feet per second.	Coefficient of Friction.				
		·15	·20	·25	·30	·35
20	29⅓	746	560	448	373	320
30	44	1680	1260	1008	840	720
40	58⅔	2987	2240	1792	1493	1280
45	66	3774	2830	2264	1887	1617
50	73⅓	4666	3500	2800	2333	2000
55	80⅔	5646	4235	3388	2823	2420
60	88	6720	5040	4040	3360	2880

TABLE C.

Nature of Surfaces in Contact.	Coefficient of Friction.	Limiting Angle of Resistance.	Authority.
		0° 1′	
1. Polished steel on polished wood	·25	14° 2′	Ferguson.
2. Metals on oak—dry	·50 to ·60	26½° to 31°	Rankine.
„ „ wet	·24 „ ·26	13½° „ 14½°	„
„ „ greasy	·20	11½°	„
3. Metals on elm—dry	·20 to ·25	11½° to 14°	„
4. Metals on metals—dry	·15 „ ·20	8½° to 11½°	„
„ „ wet and clean	·30	16½°	„
„ „ greasy	·14	8°	„
5. Leather on metals—dry	·56	29½°	„
„ „ wet	·36	20°	„
„ „ greasy ..	·23	13°	„
6. Steel on ice	·014	0° 49′	Rennie.
7. Brass on steel	·14	7° 54′	„
8. Soft steel on soft steel	·146	8° 18′	„
9. Cast iron on steel	·15	8° 36′	„
10. Wrought iron on wrought iron ..	·16	9° 5′	„
11. Tin on wrought iron	·18	10° 15′	„
12. Soft steel on wrought iron ..	·19	10° 43′	„
13. Cast iron on cast iron—wet ..	·314	17° 0′	Morin.

NOTE.—Those coefficients in the above Table ascribed to Professor Rankine have been taken from his work on 'Civil Engineering,' and are founded on the experiments of General Morin and others. Those ascribed to Mr. Rennie were made under pressure of 36 lbs. to the square inch.

TABLE D.

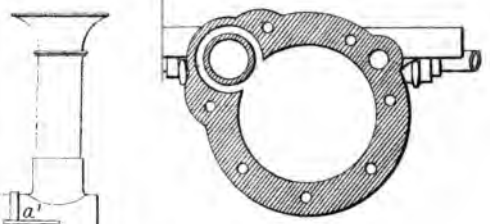
OBSERVATIONS made on the GREAT EASTERN RAILWAY between EPPING and THEYDON BOIS STATIONS as to the RETARDING FORCE required to STOP a TRAIN of a given WEIGHT moving at certain VELOCITIES.

Date.	Kind of Weather.	Total Weight of Train, including Passengers.	No. of Carriages, including 2 Vans.	Average Weight of Carriage only.	Weight of Engine and Tender.	No. of Carriages fitted with Brake.	Pressure on Gauge.	Velocity per hour.	Gradient.	Distance travelled after Brake applied.	Equivalent Distance on Level.	Time to stop Train.	Pressure applied to each Wheel of 11 Carriages.	Coefficients of Friction obtained.	Remarks.
		tons.		tons.	tons.		lbs.	miles.	rise.	yds.	yds.(about)	seconds.			
Oct. 23	Very wet	140	13	7¼	44	11	90	45	1–330	440	490	35	1125	·262	Twelve carriages fitted. One disabled.
Nov. 12	Dry ..	140	13	7¼	44	11	110	42	1–330	240	260	20	1375	·352	
„ 13	„ ..	140	13	7¼	44	11	115	42	1–330	230	250	20	1437	·348	
„ 23	Wet ..	140	13	7¼	44	11	90	40	1–330	340	370	34	1125	·275	
„ 26	Dry ..	140	13	7¼	44	11	140	50	1–330	220	250	17	1750	·40	
„ 29	„ ..	140	13	7¼	44	11	150	45	1–330	200	220	19	1875	·35	
„ 30	Greasy	140	13	7¼	44	11	130	45	1–330	400	440	28	1625	·19	

NOTE.—The author has deducted 10 per cent. from the total weight of the train, to compensate for the guard and driver applying their brakes near the end of the distance in which the stops are made; so that the total weight of the train being 140 tons, we have weight retarded by the hydraulic brake fitted to 11 carriages = 140 − 14 = 126 tons, or $\frac{126}{11}$ = to an average say of 11½ tons per carriage. The area of the cylinders attached to the blocks is 12½ in.; but as the pressure upon the wheel is doubled by their action, we may consider the pressure in cylinders as applied to each wheel—two cylinders being fitted to each carriage.

PLATE 1.

3 .



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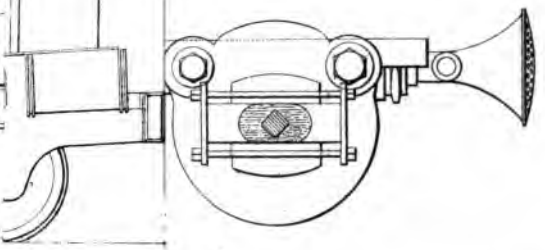
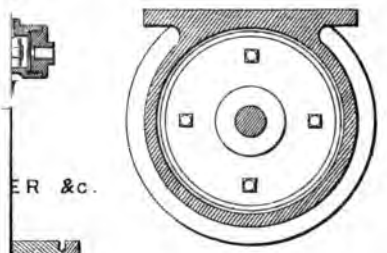
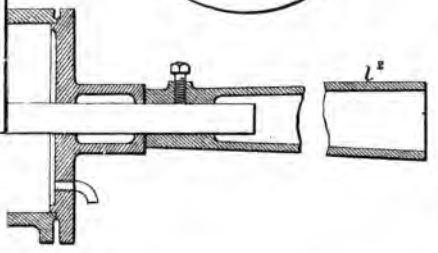


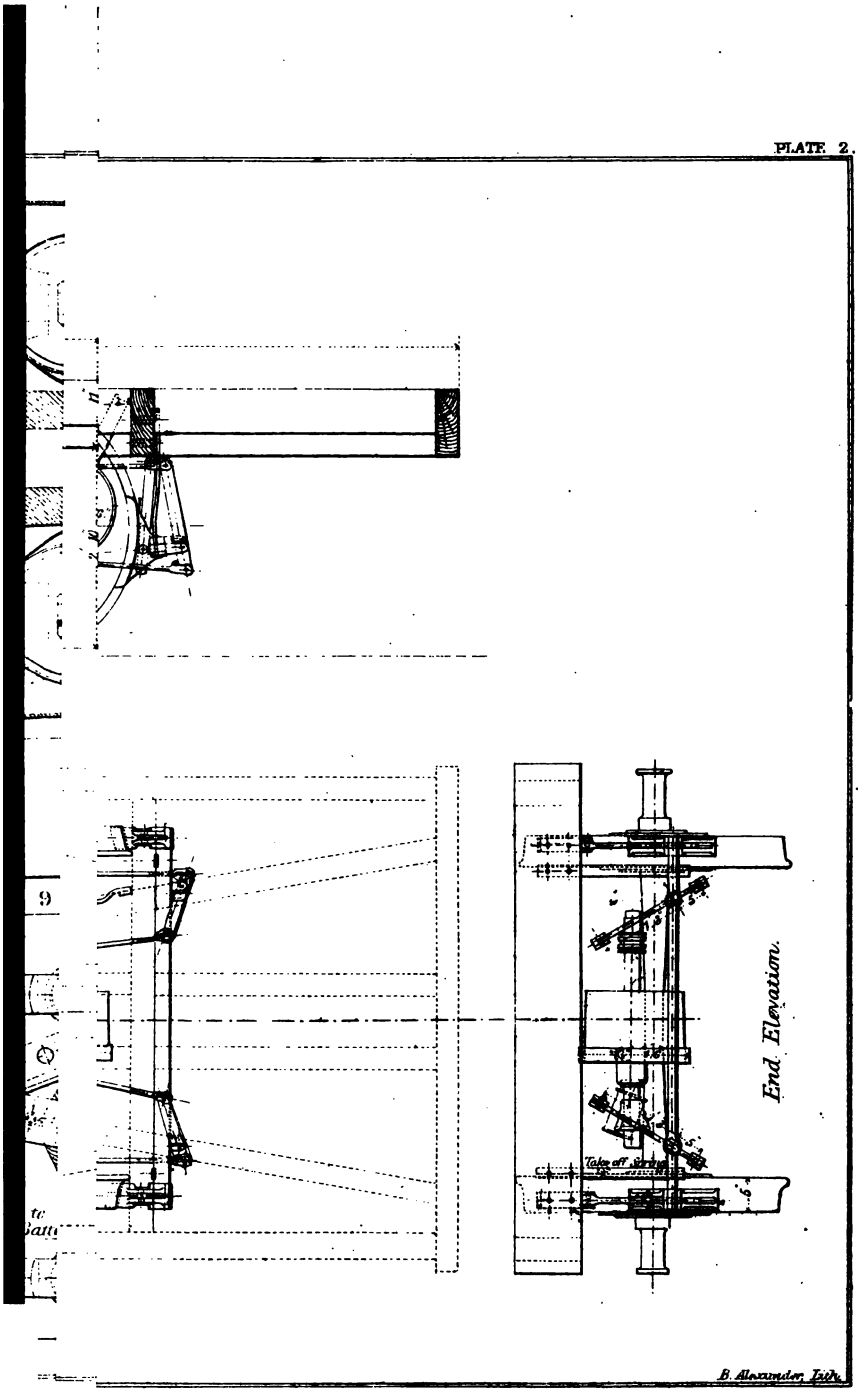
g 4 .



ER &c.



B. Alexander, Lith. 33 Castle St. Edinburgh.


End Elevation.
Take off Strap

PUBLIC LIBRARY

April 7th, 1873.

JABEZ CHURCH, PRESIDENT, IN THE CHAIR.

HORSE RAILWAYS AND STREET TRAMWAYS.

By HENRY GORE.

One of the most prominent features which mark the state of civilization of a country is the facility that is offered for internal communication between its inhabitants. Good roads invariably indicate the progress of every people, and the history of road making in England would form an interesting chronicle of the steady advancement we have made from the rudest barbarism to a condition of the most refined civilization. The early inhabitants of these islands were content with rude dwellings, rough fare, and but scant clothing; the necessity for roads scarcely existed, wheel carriages being almost unknown. They traversed the country on their strong and trusty steeds, and the patient pack-horse furnished them with all they required as a beast of burden to transport the produce of their fields or the few articles of merchandise in which they traded. But when the Romans became the masters of the land, they speedily commenced the construction of a system of roads, the remains of which we find even to this day. The growing importance and wealth of the inhabitants of the larger towns and villages soon rendered it necessary that roads or thoroughfares should be formed, so as to afford the means of easy communication between the several parts of the town or city itself and its surrounding suburbs, until at last the country became intersected by what were afterwards called the king's highways. Eventually it became necessary that these highways should be connected with the smaller villages and hamlets. This brought into existence what are still to be found in most parts of England, the parish roads, they being, as their name implies, made and kept in repair by rates levied on the owners and occupiers of land in the parish through which they passed.

But these thoroughfares became, through inattention and want of efficient repairs, inadequate to meet the rapidly increasing movement of the people and merchandise. To remedy these defects the idea was started of making and maintaining roads by private capitalists; the interest on the capital so invested

was to be secured by the levying of tolls upon vehicles, animals, and, in some instances, on foot passengers who travelled over these roads. It was from a peculiar form of gate or stile being used on some of the earliest of them, that they were called turnpike or toll-bar roads. With the great increase of traffic on these roads came the consideration of the important question of maintenance. About the end of the last century engineers began seriously to turn their attention to what may be called the science of road making. Among many eminent men who were engaged in endeavouring to improve our roads, the names of Telford, Parnell, Nichols, Macadam, and McNeil are the most prominent, and many of the great roads made by these distinguished men remain as models to this day. But perfect as our roadways were becoming they were found to be totally inadequate to keep pace with the vast development of the industrial and commercial enterprise of the country, which may be said to have commenced with the present century. To meet the demand thus occasioned, more especially in the transport of coal and raw materials and manufactured goods, canals had been constructed in many parts of the country, but the passenger traffic in the manufacturing districts exceeded the capabilities of the ordinary public conveyances, and the possibility of applying steam or other mechanical power as a substitute for, or supplementary to, animal traction was engaging the attention of engineers and inventors. Improvements in the construction of railways and machinery for working them were introduced, and the passenger railway system was inaugurated. From that time to the present important improvements have been made in public carriages, and within the last two or three years tramways or horse railways have been introduced into the streets and thoroughfares of the metropolis and several of our most important provincial towns.

Before proceeding to the consideration of the various systems on which tramways have lately been constructed, the author believes it may be interesting to detail a few of the more prominent points in the history of this description of road. The idea of a track or tramway seems first to have suggested itself to the owners of the collieries on the banks of the rivers Tyne and Wear. The first mention of such a tramway is to be found in a report made by the Lord Keeper Guildford in 1676. Speaking of the conveyance of coals, he thus describes the "wagons and wagon ways," as he calls them: "The manner of the carriage is by laying rails of timber from the colliery down to exactly straight and parallel, and bulky carts are rowlets, or wheels fitting these rails, whereby the so easy that one horse will draw down four or five

chaldrons of coals. In situations where these roads were inclined no horse was required to draw the wagons, as without such aid they ran along very readily, sometimes too rapidly if the attendant fails to apply the tiller," a name his lordship evidently intends should mean the brake. A reference to Figs. 1 and 2 will explain the general mode of constructing these roads. The wooden tramway continued in use for nearly a century. The first authentic record of the use of iron appears in the accounts of the Coalbrookdale Ironworks, where mention is made of six tons of iron rails having been cast in 1767. In 1776 Mr. Carr, the manager of the Duke of Norfolk's collieries at Sheffield, laid an iron tramway from the pithead to the staith or loading place. Figs. 3, 4, 5, and 6 show the details of these tramways; the author so lately as 1856 saw one of the platforms or wagons originally designed for this road. About this time tramways with iron rails began to be laid in most of the mining districts of the North, also in Wales and Cornwall, and it was upon one of these roads that Trevithick's locomotive engine first ran.

By a singular coincidence it is exactly seventy years ago, namely, in March, 1803, that the first mention is made of laying tramways in the public roads; it will be found in a patent granted to a person named Woodhouse, the title being "A New Method of making Iron Railroads or Ways for the use of Carriages on Public or other Roads." Figs. 7 and 8 will show the details of construction. The inventor proposed to lay cast-iron tram plates on a level with the surface of the ordinary roadway, or paved street; these plates or rails were cast in lengths of about 5 feet, and were to be supported on blocks, made either of iron, timber, or stone, the plates being secured to the blocks by means of wrought-iron bolts and nuts. The road was to be kept to a uniform gauge by means of transverse bars of iron or timber, fastened into the bearing blocks, as a security against horses slipping at the points where it was necessary for lines to cross each other. The invention provides for the use of diced or chequered plates. The rails or tram plates were to be slightly concaved; as soon as the blocks, &c., had been securely fixed the stone pavement was to be laid, if in paved streets, but in a gravel or broken stone road the sides of the iron rails were to be protected by a row of square stones on either side, the intervening spaces to be filled up with the ordinary road material. It will possibly be in the recollection of some members of this Society that the late Mr. Brydges Adams read a paper at the Society of Arts in the year 1870, in which he advocated the use of the concave rail. A reference to Fig. 9 (Mr. Adams' rail) will show how far his ideas had been forestalled by the invention of Woodhouse. The author

has been informed that a line of tramway was laid by Woodhouse to a colliery in the neighbourhood of Leicester, and reference was made to its existence in 1821, during a parliamentary inquiry.

In 1809 a tramway, or horse railway, was projected between the towns of Gloucester and Cheltenham. An Act of Parliament was obtained, and the line was opened for traffic in the beginning of 1821. This, it is believed, was the first tramway for the conveyance of passengers. A few years after the opening of the Cheltenham tramway a similar kind of road was opened from Stratford-on-Avon to Moreton-in-the-Marsh. The line was intended principally for the conveyance of coal and grain, but passenger carriages ran on market days between the years 1825 and 1832; the author has frequently travelled over this line.

In 1829 Mr. Walker, the engineer to the West India Dock, laid down a stone tramway in the Commercial Road, between the dock entrance and Whitechapel (Fig. 10); and in 1833 Mr. McNeil proposed to construct a similar stone tramway between London and Holyhead, the traffic over which was to be by means of coaches or omnibuses propelled by steam. It was proposed to form a company with a capital of 350,000*l.* to carry out the scheme, and parliamentary powers were applied for, but the Bill was thrown out at the second reading in the House of Commons—the opposition being raised principally by parties interested in turnpike trusts. The suggestion to lay rails in the streets and thoroughfares of towns, and to work carriages with flanged wheels thereon, is said to have been first made in the United States by a French engineer of the name of Loubat; but from information the author obtained while in America, he believes proposals were made for horse railways some time previous to Loubat's scheme. There is, however, no doubt that this system of street locomotion soon became general throughout the States. In 1857 or 1858 Mr. Train made proposals for laying down tramways, or street railways, in some of the metropolitan thoroughfares, and also in several of the provincial towns in England; he also applied for and obtained concessions for tramways in several important cities on the Continent. The mode of construction adopted by Mr. Train was that known as the Philadelphia system, with some modification in the sectional form of the rail; by a reference to the Fig. 11 these modifications will be seen, and the details of construction better understood. The rails were of the section called the double fillet, which consists of a fillet at each edge of the bar or plate, but in reversed positions. On this fillet or projecting ridge the tread of the car wheel is intended to run. The rails were supported on longitudinal timbers called

stringers, which rested on cross-ties or transverse sleepers, the latter being generally placed at intervals of 4 feet apart from centre to centre. The general mode of laying the road was that adopted in most cities in the United States, but the form of rail was used only in the city of Philadelphia, and when introduced was intended to serve a double purpose, for when it was proposed to lay horse railways in that city it was suggested that, while the raised fillet or ridge would be used by the tramway cars, the lower plate would serve for the use of ordinary vehicles, the wheels of which were to be altered to suit the gauge, in some long and very broad thoroughfares; this course was adopted, but the inconvenience to traffic crossing or wishing to leave the tramway at an angle has been found so great that this form of rail is now rarely used. The adoption of this form of rail by Mr. Train in his attempts to introduce tramways into this country and on the Continent led to the objection that was raised by the public to any general adoption of this system of street locomotion; and it will be in the recollection of most present that the experimental lines laid from the Marble Arch to Notting Hill and along Kennington Road to the 'Horns' were both the subjects of lawsuits, and after a short existence were compelled to be removed. A similar fate would have befallen the tramways at Birkenhead, Hanley, in the Potteries, also at Copenhagen and Geneva, had not the evil been remedied by substituting another form of rail. The inhabitants ultimately became reconciled to the existence of the tramways in their streets.

About the time Mr. Train was engaged in making his trials in England and the Continent, the author undertook the construction of a line of tramway which was to traverse the entire length of the town of Valparaiso, one of the most important ports on the west coast of South America; the length of single line of tramway was a little more than six English miles, and was constructed mainly on what is known as the loop principle, which means that the outgoing journey was performed principally along one line of streets and the return journey along another, except where, from the peculiar position of the town, only one street existed; here both lines of tramway were laid in the same street. The mode of construction was a modification of that usually adopted in the United States, one peculiar feature being that the longitudinal sleepers were secured to the cross-ties by bolts and nuts, the longitudinals were all made with scarfed joints, and were bolted up into frames before being brought to the street trench; these when laid formed a continuous frame of timber, which was levelled, straightened, and packed up, and rammed thoroughly solid before the rails were

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attached. Figs. 12 and 13 show a plan and section of the line and the general details of construction. The rail was of the section called the double bead, the pavement being laid level with the top surface of the rail, the beads forming the groove for receiving the flange of the wheel. Another modification was the use of coarse threaded screws, instead of spikes, for fastening down the rails. The cars used for the traffic were somewhat different to the ordinary tramway car, inasmuch as they had only one platform for the conductor and the entrance of the passengers. The driver was seated as in an ordinary omnibus; the cars were reversed at the end of each round journey by means of a turn-table of very simple construction, placed at the entrance of the depôt. There are several curves of 35 feet radius, two of them reverse curves, on an incline of 1 in 23. The cars traverse these curves every minute and a half from eight o'clock in the morning until half-past eleven at night, without the slightest difficulty, the outer rail being substituted by a flat plate.

The success which had attended the Valparaiso urban or street railway led the author to make proposals for an experimental line of tramway in one of the suburbs of the metropolis in 1865, but other engagements causing him to leave England, it was not until the parliamentary session of 1869 that he became intimately connected with the movement then being made for the introduction of tramways into the metropolis and some of the larger towns in the country. Since 1870 the author has designed and constructed a line of tramway throughout the entire length of the town of Madrid, and has recently returned from India, which he visited for the purpose of obtaining the requisite powers to lay tramways in some of the principal cities. Street tramways are now in operation in the metropolis, Birmingham, Liverpool, Leeds, Plymouth, Devonport, Edinburgh, Glasgow, Dublin, Belfast, and Cardiff.

Having brought the history of tramways down to the present time, the author will now proceed to explain the various methods adopted in constructing tramways in this country since the parliamentary sanction has been obtained. It must be borne in mind that one of the fundamental requirements insisted upon by the Legislature is, that the tramways in any public thoroughfare shall in no way cause obstructions, or impede the free use of every part of the street by the public, either as pedestrians or when using vehicles of the ordinary kind. This restriction necessitated the employment of a form of rail which, while it enabled a flanged wheel to be used on the tramway cars, would present a uniform level surface for the passage of ordinary carriages. The form of rails is called the grooved section, types of which are shown at Figs. 14 (Vienna), 15 (Philadelphia),

16 (Train), 17 (Boston), 18 (City), 19 (New York, Second Avenue). The mode of laying the English lines varies considerably from that generally adopted in America and other countries where tramways have been constructed.

In the metropolis the tramways exhibit three distinct types of construction. In the Brixton and Clapham and Kennington section of the London Company's Tramways, and the whole of the North Metropolitan Company's system, the method adopted is as follows, and is seen at Fig. 20: The stone pavement or macadam is taken out for a width sufficient for the double or single line of tramway, as the case may be, including a space equal to 2 feet beyond the outside line of rails, the depth being about 9 inches more or less; in this excavation two or four narrow trenches are dug corresponding with the longitudinal sleepers; the depth of these trenches varies with the nature of the material of the bed of the road; these trenches are filled with concrete, and brought up to the level necessary to receive the longitudinal sleepers. The material of which the concrete is made is sometimes Portland cement, and at other times hydraulic lime mixed with river ballast; on these strips of concrete the sleepers are laid. The gauge of the line is obtained by placing cast-iron clip chairs at intervals of about 4 feet apart, with a wider chair at the joints of the sleepers; in the inner lip of these chairs a slot or notch is cast slightly dovetailed, and into these notches flat iron bars fall, thus uniting the two opposite chairs and regulating the gauge. The rails are fastened to the sleepers by means of spikes driven through the rail, but where what is called the Larsen rail is used the under fillets are much deeper, and holes are drilled in these fillets, through which the stud of an ⌊ staple is driven. The strap of the staple is secured to the side of the sleeper by a clout-headed nail; the ends of the rails rest on flat iron plates let into the sleeper, thus preventing the rails jumping by vibration. After the rails are secured to the sleepers the line is put into gauge and levelled up by packing concrete under the sleepers; the entire excavation is then filled up with a layer of concrete to the height sufficient to allow the paving stones to be set, the paving is proceeded with, and the whole is then grouted and rammed. From the description just given it will be obvious that the stability of the tramway itself entirely depends on the strip of concrete on which the sleepers rest, there being no cross-ties or sleepers to assist in supporting the longitudinal, or distribute the weight over a greater surface; it is also to be observed that the maintenance of gauge is almost entirely dependent on the compactness and uniformity of the stone pavement; the slight resistance that the notch in the chair would offer to fracture cannot be looked

upon as sufficient to maintain the road in gauge supposing the support furnished by the pavement was removed or impaired.

The second type of construction is that which has been adopted on the London Street Tramway Company's system, whose lines are only laid at present within the parish of St. Pancras, is shown in Figs. 21 and 22. The peculiarity of this type is that instead of excavating trenches in the existing road bed, as in the former type, the entire excavation is carried to a depth of not less than 4 inches below the under side of the longitudinal sleeper, and a layer or platform of new concrete is laid over the entire area of the excavation of such a thickness as will bring the under side of the sleeper to the proper level without the necessity of any packing the longitudinals. The rails and cast-iron chairs, together with the mode of fastening the rails, are much the same as in the former type; but instead of the transverse tie-bars being attached to the chairs, they are secured to the longitudinal sleepers in the following manner: The tie-bar itself is of flat iron from $1\frac{3}{4}$ inch to 2 inches wide, at either end the bar is split for the length of from 4 inches to 5 inches, the pieces being turned back at right angles forming brackets, one half being turned in one direction and the other in the opposite; holes are drilled in these angle pieces, and the tie-bar is secured to the timber sleeper either by means of a small bolt and nut, a coach bolt or a spike, as the case may be. These tie-bars regulate the gauge. The stone sets used for the paving are of such a depth as to allow of 2 inches of gravel being spread over the surface of the layer of concrete, thus forming a bed for the pavement, which is laid and rammed and grouted in the usual manner.

The third type of construction is that used on the lines of tramway in the south-east district, more particularly in the section from the 'Elephant and Castle' to Blackfriars Bridge and New Cross, and also between Greenwich, Peckham, and Camberwell, and is shown in Fig. 23. In this type the surface of the original roadway is removed, and the ground excavated to the depth of from 12 inches to 14 inches. The longitudinals rest on cross-ties or transverse sleepers, which are laid in the excavation, and fastened to the longitudinals by means of cast-iron angle brackets, which are spiked to both cross-ties and sleeper; the cross-ties are placed at intervals of from 5 feet to feet apart from centre to centre; the rails are secured to the gitudinals by one or other of the methods previously cribed. The rails are brought up to the proper level by king the cross-ties and longitudinals with concrete, the aces between the cross-ties and the longitudinal sleepers are on with lime concrete to the height necessary for

receiving the stone pavement or the layer of asphalte, as the case may be; in some parts of these lines asphalte has been used instead of granite paving.

One or other of the modes of construction just described has, with but slight modifications, been adopted in the majority of the provincial towns where tramways have been laid, the exceptions being Glasgow, Leeds, and Birmingham. In Glasgow a special type of construction has been carried out, which the author will describe; it is shown in Fig. 24. The existing pavement or macadam roadway is taken up and an excavation made the entire width of a double line of tramway; the depth of this excavation is generally about 16 inches. As soon as the necessary depth is reached a layer of coarse broken stone or road metal is spread over the surface, and upon this layer of stone a quantity of hot pitch, mixed with a small quantity of gas tar, is poured sufficient to cement the stone into a solid mass; on the surface of this layer of what may be called asphalte concrete the timber cross-ties are laid, to each of which are fastened two cast-iron clip chairs at a distance corresponding with the gauge of the line; into these the longitudinal sleepers are placed, and secured by spikes passing through the sides of the chairs. The rails are also of a different section to those generally used, as, instead of two fillets at the edges of the rail, there is one broad fillet in the centre of the under side of the rail, which fits into a groove formed in the centre of the timber sleeper. The rails are secured to the longitudinals by long bolts, which pass through the rail and are fastened by nuts and clips on the under side of the sleeper, shown in Fig. 25. As soon as the sleepers and rails are straightened and brought into gauge the spaces between the cross-ties, and also the spaces at the sides of the longitudinals, are filled in with a mixture of iron slag or gravel and hot tar and pitch, the thickness of which depends on the depth of the paving stones; the stone pitching is then laid, but instead of grouting the joints with lime they are filled in with the hot tar and gravel mixture. The cross-ties and longitudinals are very carefully creosoted, or prepared with coal tar, before being laid down, and every precaution seems to be taken to secure extreme durability, and some parts of the lines are unquestionably the best specimens of tramway construction the author has yet seen in this country.

Many attempts have been made to substitute some form of chair or support, with a girder rail for the timber longitudinal; this idea seems to have suggested itself at a very early period in the history of tramways, as evidenced by the patent of 1803. In the construction of the tramways at Leeds and in Birmingham a chair and rail, patented by Mr. Joseph Kincaid, has been

tried; it is shown in Figs. 26, 27, and 28. This system consists of a series of cast-iron rail blocks or chairs, placed at intervals of about 3 feet; these blocks or chairs are fixed in a bed of concrete, and are filled in with concrete up to the level of the bed for the stone pitching. The blocks are arranged to receive either T rails or the ordinary grooved rail; in the latter case holes are drilled in the blocks, and into these holes wooden plugs are driven; the holes drilled in the groove of the rail correspond with the holes in the blocks, and ordinary rail spikes are driven into the wooden plugs, and thus secure the rail to the block. Between each block a strip of concrete is laid about 6 inches deep, and about the same width as the rail; on the surface of this the rail is bedded. The gauge of the line is maintained by means of flat iron tie-bars that are keyed into the sides of the blocks. The inventor claims for this system greater economy in construction and greatly increased durability.

Another form of continuous girder rail is that known as Page's rail, which is about to be laid down on a portion of the Dundee tramways, and is shown in Figs. 29 and 30. It consists of a cast-iron girder laid in lengths of from 5 feet to 6 feet. On the upper surface a groove is cast, which is intended to receive an angular steel rail in the form of an L reversed. On the upper surface the tread of the wheel is intended to run; the lower edge of the L is secured in the groove of the cast-iron sleeper or girder by means of keys or wedges; the sleepers rest on a continuous bed of concrete, and the cavity of the under side of the girder or sleeper is filled in with a species of cement concrete. The line is kept in gauge by means of slight wrought-iron tie-bars, which are made to fall into slots or notches left in the inner side of the girder, and are made fast by a small dove-tailed wedge or key. In order to protect the inner edge of the groove, which is cast with the sleeper, it is proposed to raise the paving stones some $\frac{1}{2}$ inch or $\frac{5}{8}$ inch in the space between the rails.

Other forms of iron construction for tramways have from time to time been proposed, including those of Mr. Greaves, Mr. Livesey, and the late Mr. Adams; but, with the exception of the two systems which have been described, the author is not aware that any practical experiments have been yet made in this country with the continuous girder, or any other form of iron permanent way for tramways. In the construction of the Buenos Ayres street railways a description of iron permanent way has been extensively used, but the author is not aware what the details of construction are.

The author having thus described the general forms of construction which have been hitherto adopted on the lines of tramway in this country, will now endeavour to point out some of

the defects which in his opinion exist in each of the systems which he has endeavoured to describe. In judging of the value of any system of construction, as applied to horse railways and street tramways, it is necessary to distinguish between an ordinary railway and a street tramway. It is true that in both cases the vehicles employed are intended to move as far as practicable in uniform straight lines, and that in passing from one point to another they are to travel over the shortest route that circumstances will admit of their taking; also as to the surfaces upon which the wheels of the carriages are to run, namely, iron rails, railways and tramways are alike. Beyond these conditions the similarity between a railway and a tramway ceases. In the former, the road and all its accessories being reserved exclusively for the special class of carriages intended to be used, a form of rail can be employed which, while presenting a perfect surface over which the wheels have to travel, at the same time presents the maximum resistance to vibratory action; and, moreover, as it is raised considerably above the surface of the ballast or earth, always presents a perfectly clean surface, so that the friction in running over it is reduced to the minimum. Another important feature is that no derangement of gauge is likely to take place from lateral disturbance caused by anything passing over or striking the rail at any angle. A street tramway, on the other hand, is exposed to many serious inconveniences that can never attach to a railway. To begin, the very form of the rail itself is an important difficulty; the use of the public streets by other vehicles renders it necessary that a uniform surface should be maintained over the entire width, therefore the tram rail must as nearly as possible be a mere bar in shape, with some provision for maintaining the parallel position of the car or carriage which is to travel upon it. This necessitates the sunken groove, and only one of such dimensions as will not admit of the entry of the wheels of ordinary carriages. To comply with these conditions we sacrifice one-half of the first advantage to be gained by the wheel rolling over the smooth surface. This loss is occasioned by the friction of the flange in the groove. Then, again, the rail being on the same level as the paving or macadam, is more or less constantly covered with a coating of mud or dirt, which materially increases the friction, and as a matter of course adds to the cost of haulage. But these are not the only drawbacks. The flat rail is sure to attract all the heavy traffic in ordinary vehicles, because, as their wheels are not hampered with the flange, they simply roll over the smooth surface. Now, the effect of this class of traffic on a tramway is to increase very materially the amount of vibration, while from the nature of the road this vibration is transmitted

through a considerable length of line. The effect is to dislocate or break up the bed of the road by a process of pulverizing the road material. Then, again, the passage of other vehicles across a tramway at every possible angle has a tendency to disturb the gauge by constant concussions. It will thus be evident that a tramway is constantly subject to injuries and disturbances that scarcely apply in the slightest degree to railways. If such disadvantages are inherent to street tramways, it is obviously the duty of those engaged in their construction to apply themselves to such a course of procedure as will reduce the evils complained of to the minimum; and no system of construction should be advocated or tolerated that increases the defects which unavoidably belong to tramways; but it is to be feared that the system which has found most favour in the metropolis, and in most other places in this country, does add very largely to the inherent imperfections of our tramways.

The first and most important defect in the present system of tramway construction consists, in the author's opinion, in the use of concrete as a base for the sleepers and rails. Having had many opportunities of observing the effects of concussion and vibration on masses of concrete, he has invariably found that nothing is so detrimental to its cohesion as exposure to slight but constant vibration; the effect being to break up the small particles of lime or cement nearest the vibrating body, thus enlarging the range of action, until at last a pumping motion is produced that soon destroys the cohesion of the entire mass. That this effect is produced on many of the lines of tramway where the longitudinals rest exclusively on strips or a bed of concrete, is abundantly evident by watching the motion of the rails after wet weather. The material of the concrete is constantly being pumped up to the surface by the vibration of the rail and sleeper. That such would be the effect might have been foreseen by what has been constantly taking place on the Great Western Railway, where longitudinal timber sleepers have been used. In many cases channels of from one-half to three-quarters of an inch have been worn in the surface of the sleeper by the vibration of the iron rail; an inference may fairly be drawn that if such would be the effect on an elastic material like wood, the effect would be still greater in a comparatively friable mass like concrete.

But the employment of the concrete base and the longitudinal sleeper alone has hitherto involved a very imperfect system of lateral support and maintenance of gauge. To the most casual obser[illegible]nust be evident that the flat tie-bar, as used in the tw[illegible]es of metropolitan construction, affords an inade-q[illegible]rt to the sleepers, and may therefore be regarded as

useless, after the work of construction is complete; the sole lateral support is derived from the rigidity of the pavement, and any disarrangement or disturbance of this must of necessity affect the gauge of the line. In order fully to understand the evil here complained of it is necessary to take into consideration some of the disturbing causes. It has already been shown that the concussions caused by passing vehicles at various angles must more or less affect the parallelism of the rails; but there is a constant effect being produced by the heavy tread of the horses dragging the tramway car. This constant pounding or ramming in one uniform line has the tendency to spread the line and widen the gauge. That this is constantly taking place the author has had numberless means of proving; in fact, to such an extent has it taken place that the wheels in some cars are worn down to almost a knife edge by the friction on the inner side of the groove. A moment's reflection will show how much additional work is thrown upon the animals engaged in drawing the cars when chilled iron wheels are to be ground away in the manner just described. In addition to the mechanical defects inherent to the use of concrete support for tramways, the author believes a far more important defect is involved in the chemical influence of the lime upon the timber itself in causing its rapid decay. The serious consequences that will result from any extensive repairs or renewal being necessary in our street tramways, seem scarcely to have been calculated upon; hence defective systems of construction have been adopted, and improper materials used with the sole view of obtaining economy in first cost.

The objections to be urged against the iron permanent way system are want of elasticity, liability to fracture, and constant derangement and injury to rolling stock. The author travelled on several occasions over the portion of the line laid down at Leeds, and found the undulatory motion and shock to the car when passing the iron blocks was exceedingly disagreeable to the passengers, and must certainly be very injurious to the carriage. He had some experience in travelling over an iron permanent way in India, between Cawnpore and Lucknow, and noticed precisely the same defects as in the Leeds experiment. The author is thoroughly convinced that a certain amount of elasticity is absolutely necessary in the permanent way of tramways, and he is equally convinced that it would be very desirable to find some material more durable than timber to obtain the required elasticity; but up to the present time no such material has been forthcoming.

If time had permitted the author would have referred to many minor defects that are to be observed in the present system of

construction, particularly in reference to the laying down of curves of short radius, the imperfect manner of putting in points and crossings, both as to position and number, and also method of construction; these may be mere subordinate defects, but their existence tends very materially to increase the cost of working the tramways in this country, and in many instances to cause unnecessary inconvenience to the public.

In bringing this paper to a conclusion the author will venture to offer a few suggestions on what he believes to be the essential conditions to be observed in the construction of a street tramway, admitting of course certain unavoidable difficulties consequent on the necessity to use the grooved section of rail.

In the author's opinion the basis of the tramway should be a continuous framework of transverse and longitudinal sleepers; that the longitudinal should not rest simply upon the transverse sleeper, but it should be firmly affixed to it, either by bolts or nuts, spikes or treenails, as shown in Fig. 31; that the whole of the longitudinals should be connected together by suitable scarf joints, or in any way that would ensure perfect continuous bearings. In laying such a framework in the street or thoroughfare, he would only disturb so much of the bed of the existing roadway as was necessary for the depth of the rail and longitudinal sleeper; he would excavate narrow cross-trenches to receive the cross-ties or transverse sleepers—allowing 1 inch or 2 inches in the depth for the ramming in of dry ballast packing underneath the sleeper; he would bring up the timber sleepers to the requisite level by thoroughly ramming and packing with clean dry ballast; straighten and put the line in gauge, and then proceed to lay and secure the rails, which he prefers to do with 4-inch coarse threaded joiners' screws, or else with square chisel-pointed spikes, at the outside of the longitudinal sleeper; at each transverse sleeper he would fix a cast-iron angle bracket, carefully fitted and properly spiked to both sleepers. The whole of the line should then be thoroughly examined as to levels and correctness of gauge. The ballast may then be filled in and rammed to form a bed for the paving. The author, from his experience in the construction of tramways, believes that a thorough attention to ramming is essential to the stability of the road, and if attention is paid to this there is no necessity whatever for concrete, except, perhaps, in newly made thoroughfares.

In reference to the question of filling in the spaces between sleepers and forming the bed for stone paving, the author believes that the best material that could be used would be [illegible]or broken stone mixed with a certain portion of coal tar. [illegible] should be heated to a sufficient temperature to drive off

the free ammonia, but not to give off the essential oils; a small quantity of grease or oil should then be mixed with the warm tar to render it slightly viscid; only so much tar should be used as to perfectly paint or coat the stones, care being taken that the stones are perfectly dry before the tar is put on them. This mixture, which the author calls tar macadam, is better if kept a fortnight or three weeks before being laid on the road. A material like this laid down and thoroughly rammed or rolled will form a bed for pavement the best adapted for tramways that the author is acquainted with; it will resist any amount of pressure, is impervious to moisture, is elastic, and exerts no injurious effect upon the timbers of the sleepers. A great improvement might be made if the paving laid between the rails on tramways were left with a more open joint, and this joint filled up with small gravel and melted coal-tar pitch; the open joint would afford very material assistance to the horses in starting the car, and by using pitch instead of lime and cement grout the formation of mud during wet weather would be almost done away with. Another important point that the author would insist upon is the thorough preparation of the timber, either by means of creosote or some equally powerful antiseptic material; the objections raised against such a process on the score of expense, the author believes to be untenable when applied to the question of tramways. It has been urged that on railways the cost of creosoting, if done effectively, has been found to be greater than the putting down of a new unprepared sleeper. This may be perfectly true in reference to a railway, where the renewal of a sleeper is comparatively only the work of a few minutes, but it is quite another matter to replace a sleeper or longitudinal on a street tramway, which involves the taking up of pavement, and it may be the removal of one or more rails, and other tedious work. A moment's consideration will point out the necessity for taking every precaution to secure the maximum of durability of so perishable a material as timber when used in the construction of railways or street tramways.

There are some points connected with the laying out of tramways in particular towns and districts, and the selection of routes, that the author would have wished to have touched upon, but he fears he has already extended this paper beyond proper limits, and will therefore conclude by expressing his conviction that tramways will ultimately become important elements in carrying on the street locomotion of the important towns in the country, but at the same time he believes that hitherto the principal consideration of those engaged in the promotion of tramways has been to obtain as large as possible

returns upon the capital invested; to secure this, economy instead of efficiency has been the basis on which most of the lines have been constructed. This desire for cheapness has led to many of the defects that are now apparent, and which only time and a careful study of what street tramways really are can remedy.

DISCUSSION.

Mr. P. F. NURSEY said that Mr. Gore had referred to the propulsion of tramway carriages on ordinary roads by means of steam power, which idea appeared to have originated in the year 1803. It had been tried at various times and in various places, but it had not become a practical success down to the present time. There existed an Act of Parliament prohibiting the use of steam carriages on common roads between the hours of 10 A.M. and 6 P.M., so that that method of locomotion would not be of much use to the travelling public if it were adopted. He had lately been inspecting a steam-driven tramway car, which had been designed by Mr. Grantham. The car was of the ordinary construction, and on each side, midway of the length of the car, inside, was a casing or chamber reaching from the bottom to the top. This was about three feet wide and of the same depth as the seat. In each of these chambers was a small Field boiler and a 4-inch steam cylinder, giving altogether about 8 horse-power. The platforms of the car were each 2 feet 6 inches longer than the platforms of the present cars. The driver stood on the platform, and while he was starting, stopping, or reversing the gear, he also had the brake under his command. The conductor stood on the rear platform, and he also had a brake. On arriving at the end of the journey, the driver took the stopping and starting gear with him from one end and fixed them at the other end, which then became the front of the car, the conductor also changing ends. The car ran upon two pairs of solid disc steel wheels 2 feet 6 inches in diameter, and was driven from one pair of the wheels. The two boilers led to one common flue, and there was a short chimney just above the top of the car. The car was built by the Oldbrook Carriage Company, and the engines and boilers were made by Messrs. Merryweather and Sons. It was recently to be seen at work under an arch of the South-Western Railway at Lambeth, but as it had only twice its own length to run in, no criterion of its working could be got from that trial, except the fact that it was very readily stopped and started, and answered immediately to the regulator, and that the noise of the engine was very slight indeed. Mr. Grantham appeared to have reduced the great disadvantage of

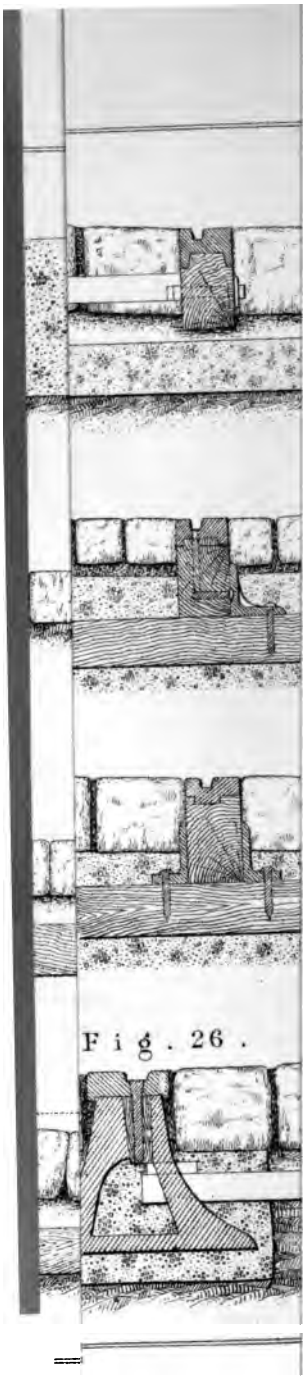


Fig. 26.

the noise attending a road engine to a minimum. The inventor had had an offer from a tramway company to try this car upon a long length of line which was not yet open to the public. That would afford a very good opportunity of judging of its merits. The only difficulty was whether the Board of Works or the Local Board would oppose its running. As far as he (Mr. Nursey) could judge of the working of the steam car in the shed, it approached very closely to success. His opinion was, however, that it would be better to drive the car from one end only. What was wanted for steam-driven tram cars was a very light engine and boiler, giving a good economy of fuel. The working model of such an engine he (Mr. Nursey) had recently had to inspect. It had been invented by Messrs. Moy and Shill, and was exceedingly light, and the working of the model was certainly unexceptionable. It could be worked at very high pressures and quick speeds with great economy, the maximum of expansion being effected in it. The cylinder was enclosed within the boiler; the steam was generated both in the boiler and in two sets of projecting tubes. The principle upon which it was based was correct, and it seemed that, worked out in practice, it would form a desirable apparatus for such light purposes as driving tramway cars and similar objects. He believed that an engine of 10 horse-power designed upon that principle was being constructed, and would be brought before the public shortly.

Upon the general question of tramways, there was one point to which he would refer. It appeared to him that the great defect of tramways at present was the subsidence of the stone pitching on each side of the rail, which was an important matter in tramway maintenance. He spoke from experience of the defective condition of the tramway between Westminster and Brixton and Clapham. Mr. Gore proposed to remedy the defect by the compound arrangement of which he had spoken. He (Mr. Nursey) would like to know whether the author had had any experience of that arrangement, and whether it had been tried. It really seemed that the desideratum in tramway construction was a good, sound, permanent road, which would always maintain its own level instead of constantly subsiding. Although on the present roads in the south of London there was very good concrete bottom and the rail level was well maintained, the granite pitching was constantly under repair, and appeared to be a source of endless trouble in maintenance.

Mr. KERSHAW said that in Islington a kind of asphalte paving made of tar and macadam was laid for the purpose of overcoming the difficulty arising from the macadam stones sinking at the side of the tramway rails; but it was found in practice

that the vibration of the rails from the cars and other vehicles passing over disintegrated tar paving adjacent to the rails, and that when the stones got loose the ordinary traffic ground the paving to dust and mud for about 9 inches or a foot on each side of the rails. The tar paving had to be repaired about every week in the short length of roadway from Islington Green to Barnsbury Street, along the Upper Street. The repairs continued for about six months, the tar paving having worn out after the first three months. The company had now substituted for the tar macadam 6-inch granite cubes in a double row on each side of the rail, and the joints were filled in with tar. He did not think that would answer for any considerable time. Granite paving set on concrete, with joints filled in with tar had been tried in Fleet Street, near Temple Bar, and in Great Queen Street, Lincoln's Inn Fields, and in one or two other places. The tar after a time got brittle, and the stones worked loose.

Mr. F. W. HARTLEY observed that Mr. Gore had said that he fancied that the gauge of the rails increased in time. He (Mr. Hartley) doubted the correctness of such fancy. Of course no one could be surprised that the rails should get cut away, especially in the curves; but he would ask Mr. Gore whether he had made any absolute measurements so as to determine whether there was really a widening of the gauge apart from the wear produced by the wheels. As far as the substratum was concerned, he thought that concrete did not form a good basis for the tramways.

Like Mr. Nursey, he was in the habit of using the Brixton and Clapham tramways, and he fancied that there was now more vibration than there used to be. He had also noticed the breaking away of the material at the sides of the rails. It did not, however, seem that the rails sank at all. Granite pitching and macadam had both been tried for keeping up the sides, but both appeared to fail, and a vital point yet to be secured was the formation of a perfect union between the rail and the road.

Mr. THOMAS MOY said that as Mr. Nursey had referred to his invention, he would state that he (Mr. Moy) thought that the future of tramways would certainly be connected with the use of steam. He had been endeavouring to adapt the engine invented by himself and Mr. Shill to the driving of tramway cars. There were some points requiring careful consideration in accomplishing that object, and one special point was the shunting; if both wheels went together, of course the shunting would be a difficulty. Their engine was, as Mr. Nursey had said, very light; it could be constructed as light as 7 lbs. to the horse-power. For a tramway car they might weigh 10 or 12 lbs. per horse-power. It was intended to use very high pressure

steam and a strong generator. Everything in the shape of an ordinary boiler was quite eliminated. With the generator of their engine they could work at 300 or 400 lbs. to the square inch. They could pass the exhaust steam into a surface condenser, and use the water over and over again. All noise which could frighten horses would be done away with. The quantity of fuel consumed would be very small, as, by the use of very high pressure and expansion, great economy was attained. He believed that in the course of the next twelve months they should be able to adapt their engine to tramways and drive the cars with ease, and also to manage the shunting. As to the wear of the present roadways, it would be found that the stones were generally put somewhat in an arched form. Of course the tramp of the horses pressed down the crown of that arch, and drove apart the longitudinals, and thus the gauge became widened. That was a very great defect of the present tramways. When steam came into use that defect would not arise.

Mr. CARGILL asked whether the section of rail shown by Mr. Gore as Train's section was the same as used on Mr. Train's trial line from the Marble Arch. He (Mr. Cargill) believed that the reason that Train's trial lines were taken up was not that there was any absolute defect in the form of the rail, but that Train failed to procure that protection without which it was useless for anybody in this country to try any new enterprise of that kind. Train had no Act of Parliament, and he laid down his trial lines on sufferance under the permission of the vestries. There were one or two points on which he should like to make some remarks. One was the use of tarred macadam. He did not believe that gas-tar macadam, or stones with open joints filled in with tar, ever made a good job. Wooden blocks and tar would, but stone blocks and tar would not. One of the best examples of paving with wooden blocks and tar was that laid down by the church of St. Mary-le-Strand. That had been down about six or seven months, and, considering the traffic there, it gave decidedly the best results. He believed that there were not yet any signs of wear. The great difficulty in combinations of large and small stones was that the surface wore unevenly and sank into ruts. No doubt, as Mr. Moy had said, the tendency of arching the roadway between the rails of a tramway was to throw the line out of gauge; but, on the other hand, if the road was laid flat in the first instance it would very soon sink in the centre. The object of the arching was to maintain the level of the road, but a very slight curve was sufficient for the purpose. As to the use of creosote for timber, he did not think that engineers now put that confidence in the various preservative processes that they used. It had been said

that good timber did not need creosote, and that it was very little the better for it, and that it was a question whether the process in the long run very much improved bad timber. The great use that was once made of creosote was simply a premium upon the employment of bad timber. He could never see the exact use of the ties in the Kennington Road Tramway, and he doubted whether they ever filled the office they were intended for. If the tramway was to be kept in gauge at all it must be by the pressure of the parts surrounding it. The ties in the Kennington Road were perfectly useless. They were too slight, and the method of simply dropping the ends into slots was very crude. The other method, in which the rod was split, was better, although it would be as well if that were bent over and fastened on the one bolt. He thought that the large groove in the Glasgow tramway rail must very much weaken the timber. Fig. 11 seemed to show the best kind of rail.

Mr. NURSEY said he believed that the real cause of the failure of Train's tramway was its defective construction. The form of rail was bad, and to his own knowledge a great many accidents had happened, besides the breaking of axles and the twisting of wheels. Possibly, also, Mr. Train failed to pave the way to success by having evinced a disposition to provoke rather than to conciliate opposition.

Mr. J. H. ADAMS asked Mr. Gore for what reason he had a groove on each side of the Valparaiso rail. It differed from all others in that respect. He should suppose that the groove was required only on the inside. Perhaps, also, Mr. Gore would describe the very simple turn-table which was used at Valparaiso. Mr. Nursey had said that the tramway steam engine which he had examined made very little noise. Was the load on it such as to afford a fair criterion of the noise which would be made in actual traffic?

Mr. NURSEY replied that there was really no great weight upon it, and that was why he suggested that a trial under the practical conditions of ordinary traffic would be the true test of its efficiency.

Mr. J. H. ADAMS further inquired whether the engine of Mr. Moy of which Mr. Nursey had spoken was intended to run upon separate wheels or to form part of the tram carriage.

Mr. MOY said that they could work it either way. The engine could be put upon the platform of the car and drive one or two pairs of wheels, and occupy very little room; or it could be put upon a separate carriage. It was a very light engine, and it was adaptable to every purpose for which a locomotive was required.

Mr. DRUITT HALPIN said that there was an engine running

on a common road between Edinburgh and Portobello, a distance of 6 miles. There was a kind of Field boiler at one end of the platform. One wheel swivelled, as in a ploughing engine, and the engine was steered from there. There were three cylinders in the body of the coach underneath the feet of the passengers, and working on to the driving axle. The driving axle carried the greater part of the weight, and there was sufficient adhesion to propel the whole machine. The driver, of course, went first and steered the engine. The exhaust was taken up into a box, which formed a seat for the outside passengers on the top of the omnibus. The Act of Parliament required that such machines should be preceded at a distance of 40 yards by a man carrying a red flag. In this case the man was dressed entirely in red, and succeeded admirably in frightening horses. He (Mr. Halpin) did not know how the car answered as a commercial speculation, but the engine was entirely under control, and attained the speed of 8 miles an hour up a gradient of 1 in 25 or 30. The noise was very slight. He wished to ask the author of the paper the cost of the tramways per mile, and also whether he had any data as to the cost of asphalting as adopted in the Poultry, or as to the friction of the tramways. He (Mr. Halpin) believed that the friction of the asphalte had never been determined. It was an important question whether, considering the expense of making and maintaining tramways, it would not be better to asphalte the whole road, and so reduce its friction, and thus enable the whole mass of the traffic to avail itself of the improvement rather than simply to lay rails for the tramway cars. Upon the asphalted roads could be introduced a proper system of omnibus, which should be easily accessible by means of low steps. As to the sleepers the author said that timber was the only material which combined strength with a moderate degree of elasticity, but the objection to its use was its liability to perish. There were, however, many useful forms of continuous wrought-iron sleepers. Among them was Livesey's Patent Sleeper, which made an exceedingly soft riding road.

Mr. J. J. Miller said that there appeared to be an utter want of drainage where the tramway sleepers were laid in concrete. Where asphalte was used it seemed to be impossible to keep the rails level with the surface of the road. A short section laid in asphalte from the 'Elephant and Castle' to the Chatham and Dover Railway bridge in the Walworth Road was a constant source of annoyance, and was kept in a state of constant repair, especially in wet weather. Another source of difficulty was the junction between the stone pitching outside the rails and the macadam, which was constantly out of line.

Mr. GORE, in replying upon the discussion, said that he did not advocate the use of asphalte as a surface, to which Mr. Kershaw had alluded. He objected to it for two reasons: the first was that the action of the horses' feet would wear the asphalte into ruts and break up the line; and the second was that, under certain conditions of weather, the starting of the horses was almost a physical impossibility in connection with the haulage of the cars. What he advocated in regard to tar paving was its use to form a surface upon which the stone pitching should be placed. He believed it was impossible to construct a tramway in any city or town where there was a large traffic, unless a surface of stone or some equally hard substance was used. He could endorse Mr. Hartley's views in reference to the constant widening of the wheels, and the effect produced upon the axle boxes of the wheels by the wrenching to which they were subject in passing points and crossings. But the most important point in reference to the widening of the gauge was undoubtedly the effect of the tread of the horses in two continuous lines; and it must be borne in mind that most of the heavy ordinary traffic of a road is passed along the tramway. The effect of the constant beating down of the surface by the heavy trampling was to widen the gauge. In answer to Mr. Cargill's question as to the form of some of the rails, the diagram was an exact copy of a rail used by Mr. Train. He (Mr. Gore) believed that to a great extent Mr. Nursey's views as to Train's want of success were correct. He (Mr. Gore) had it on the authority of the chairman and the surveyor of one of the most important vestries in London that had Mr. Train shown a little more of the *suaviter in modo* in his transactions the difficulties as to the rails might have been overcome. He must confess that he could not agree with Mr. Cargill as to the use of gas-tar and macadam and wooden blocks. He objected to it on the same ground that he had objected to the use of asphalte, for it was almost impossible to start the horses on wooden blocks, especially on an incline; that fact was brought out in the dispute as to the Camden Road line. He also differed from Mr. Cargill as to the use of creosote. The success of the creosoting process was a question of time. If the creosote was naturally absorbed by the wood, instead of being forced into the pores by pressure, it would, he believed, act as a preservative. Chemically speaking, it must be so, because the creosote replaced a perishable ingredient in the wood by an imperishable one. On the west coast of South America he had seen wood which had been creosoted by simple absorption, and had remained thoroughly sound after ten years' use; that wood was never subjected to any compression in the process. In the

same structure piles, which had been prepared by compression, had decayed, while those which had been prepared by absorption were still sound.

The reason for using a double form of rail in Valparaiso was that iron was a very expensive commodity there, and it was thought that it would be a saving of money to have the rail double, so that when the upper side wore the rail could be turned over and used again. The cost of the rails delivered in Valparaiso was 24*l.* or 25*l.* per ton. The turn-table of which he had spoken was simply formed of slabs nailed together and placed upon eight cannon balls. The cost per mile of tramways had varied very considerably. Some lines had been laid down for 1300*l.* per mile, exclusive of stone paving, while others had cost 2500*l.* or 2800*l.*, also exclusive of stone paving. The whole range of variation had been from about 4500*l.* up to 7000*l.*, including stone paving. All the estimates were for single lines. The line in Madrid had cost, including freight, Custom-house duties, &c., 3600*l.* per mile. He was afraid to say what the Glasgow line had cost, but money was not considered in the question. The quotations for asphalte had varied from 5*s.* 6*d.* to 17*s.* per square yard. The Val de Travers Company had made propositions in some cases to lay down their asphalte at from 15*s.* 6*d.* to 16*s.* a yard. He believed that some portions of the Peckham and Greenwich line had been asphalted at that price.

Mr. T. CARGILL said that the asphalte in the Poultry cost 18*s.* 6*d.* a yard under contract.

Mr. GORE said that he quite agreed as to the importance of calculating the friction of tramways. The question had never been thoroughly considered. The wear and tear of horse flesh was enormous, and there could be no doubt that the necessity of using a grooved rail was a great drawback to the employment of horse power. He was not able to give an answer to the inquiry as to the cost of maintenance of tramways. The companies were fixing the cost at various sums, but his own opinion was that it would be, very shortly, far more serious than was calculated. There must be a more substantial system of first construction. With reference to Livesey's sleeper, he (Mr. Gore) had travelled for 80 miles upon it on the Cawnpore and Lucknow Railway, and he did not consider the journey a very great pleasure. Wilson's rail was used originally upon that line, but it appeared to have been abandoned. It consisted of corrugated chairs, or transverse sleepers, upon which the rail was bolted. He was told by the engineers on that section of the line that the objection to that sleeper was the impossibility of keeping up the road. He agreed with Mr. Miller as to the want of

drainage on tramways, and that was his reason for insisting on dry ballast, well rammed, to secure that drainage which he was sure could never be obtained where concrete was used.

The PRESIDENT said that the paper was one of some importance, because it related to our comfort and convenience in our every-day transit from place to place. The author had laid down certain conditions which were very important and ought to be insisted upon. One condition was that no tramway ought to impede the ordinary traffic of a road. That was one point in which Mr. Train's tramway entirely failed. Another condition was elasticity, and that was as necessary for tramways as for railways. As to the concrete, that was a material which required to be free from the ordinary influences of the atmosphere and of drainage if it was to be used successfully. When it was placed at a good distance below the surface of the ground and was covered by a mass of brickwork, it made a good foundation; but if it was to be exposed to ordinary atmospheric changes it would not be a suitable material for the foundation of tramway sleepers. He believed that the ultimate success of tramways depended upon the use of steam power instead of horse power, and he expressed that opinion in this Society some years ago. He was very glad to hear such promising accounts of Mr. Grantham's steam tram-car and Mr. Moy's engine. It was simply a disgrace to engineers that they had not hitherto adapted steam power to tramway purposes. It was essentially necessary, not only in London, but all over the kingdom. Reference had been made to the Act of Parliament, but it must be remembered that the Act was directed against the objectionable traction engines which were the only kind of locomotives at present used on common roads. It was not fair to compare such engines with the engines which he hoped would before long be introduced on tramways. The construction of a suitable engine for tramway use was a field open to English engineers, and he hoped that they would prove themselves equal to the requirements of the case. He had had considerable experience of creosoting timber, and he could say that, as far as that experience went, the creosoting of the present day was not at all equal to the creosoting of twenty-five years ago. He believed that it was falling into that system of cheapness which had led to so much disaster and ruin. He had great faith in the preserving qualities of creosote if it was forced, under pressure, into timber from the pores of which the air had been previously exhausted. He believed that the failure of creosote was due to a lack of attention, in recent years, to the details of the process of impregnation. The question of the cost of maintaining [illegible]s had not been lost sight of in the discussion. It was

one which must always be regarded, for however good or scientific an invention might be, it must always be considered with reference to its commercial result. It appeared that the cost of the maintenance of tramways had not yet been ascertained. He could not but think that the section of rails in use at the present time was defective, and that it produced double the amount of friction which would ultimately be reached. Friction was a very serious drawback to the tramway system. Frictional resistance meant cost, and cost was a great element in all these matters. Hence tramways could not be considered at the present moment a success.

May 5th, 1873.

JABEZ CHURCH, PRESIDENT, IN THE CHAIR.

CHARGING AND DRAWING GAS RETORTS BY MACHINERY.

By JOHN SOMERVILLE.

For several years past machinery for drawing and charging retorts in gas-works has been receiving the attention of gas-engineers and managers of gas-works as a substitute for manual labour, which has become somewhat unreliable and unmanageable, the men from time to time forcing up the price of their labour by means of strikes, combinations, working shorter hours, &c. We have a recent example of this in the stokers' strike in London, which at one time appeared so formidable and assumed such gigantic proportions that all London was threatened with darkness. Too much praise cannot be given to the gentlemen at the head of the various gas-works of London for the promptitude and energy with which they met the emergency and successfully stamped out the rebellion. Had the stokers been successful, the combination would have rapidly spread throughout the provinces, and many a country town would have been in darkness, or would have had to submit to extortionate and unreasonable demands. It was very interesting and instructive in the country to watch the sayings and doings and the attitude of the men there from day to day as the daily paper was read in the retort-house, and to notice the effect of the news, whether encouraging or desponding; and there is no saying when such a strike may be repeated, as there is a scarcity of labour and a great amount of sympathy is shown to the men. But should another strike occur, it is to be hoped that it may be as successfully resisted as the last.

But there are other if not greater considerations than even strikes, which call for the introduction of machinery into retort-houses. It is an acknowledged fact and an unfailing law of manufacture that machinery cheapens production, and into whatever branch of industry machines are introduced to supersede hand labour, there follows as a natural sequence a reduction in the cost of the article produced. Directors and managers

of gas-works who intend to introduce machinery, but who are only waiting to be assured that a saving is effected by its use, should accept this as an invariable fact, that as it has hitherto been with all other classes of machinery, so it will be with that which forms the subject of this paper. Gas will be produced at a cheaper rate with mechanical aids than by purely manual labour. Another advantage attending the introduction of machinery into retort-houses claims attention from a humane point of view. It is of no use attempting to ignore the fact that far and wide there is a growing impression, not only with workmen themselves, but with men in high positions, that the work of stokers is very severe, not only tending to shorten life, but having a demoralizing effect. Although there are men who have worked twenty, and in some cases even thirty years at stoking, yet their work does not seem to have developed muscle, and they are generally tough and wiry, but with wrinkled sallow faces, from which the blood appears to be dried out. These men are working twelve hours out of every twenty-four, changing turn about, night and day, Sundays and week-days alike. There is no cessation from the one round of work and sleep, sleep and work. It is no wonder that these men meet with sympathy, and it is only natural that humanitarians and Sabbatarians should endeavour to ease and lessen this excessive toil before hot retorts by shorter hours and freeing them from Sunday labour. The efforts of these friends of the stokers could not be better supplemented than by the introduction of machinery. Although it reduces the number of men by more than one-half, yet there are numerous operations in a retort-house requiring manual labour besides stoking. What the machine does is the hard hot work of drawing out the burning coke from the retorts and replacing it with a charge of coal, so that the flame does not burst out upon a human form, as when the hand scoop is sent in, but plays harmlessly upon a mass of iron. Another point in favour of the machines is that they can be kept constantly at work, whilst, under the old system of manual labour, on pay night and holidays gas stokers either show an inconvenient preference for the public-house, or else are unfitted by drink for their duty in the retort-house.

Having shown why machinery should be introduced to perform the operation of stoking in gas-works, the author will next proceed to describe the apparatus proposed and in use for that purpose. Machinery for emptying coke ovens has for years been in use on the Continent, but the earliest form applied to the process of gas production was Clegg's revolving web retort, shown at Fig. 1. This was an arrangement by which fine coal was mechanically fed through a hopper on to a web formed of

wrought-iron boiler plates, and made to travel continuously over revolving drums, the whole being enclosed in a retort and chamber made of wrought iron, and heated by a furnace underneath. The coal was charged on to the web, and the coke, after the liberation of the gas by travelling through the retort, fell into a cooling chamber. This arrangement was the earliest form of charging and discharging by machinery, but it did not answer.

The next attempt was made in 1840 by Mr. Brunton with his discharging retort, Fig. 2, but which met with no better success than Clegg's, the same defective principle being apparent in each. The coal was discharged through a hopper, and the successive charges were propelled along the retort by the action of a piston working through a stuffing box in the retort-lid. The coke was discharged into a box containing water, into which the end of the retort dipped. It is not very difficult to imagine the condition of the coke when taken out of its water bath.

The next contrivance, shown at Fig. 3, was the first attempt at a "steam stoker." Mr. George Michael took out a patent for improvements in the manufacture of gas, and remarks in his specification, "that, with the present state of progress in the different arts which co-operate in the construction of gas-works, the power of the manufacturer may be increased, and the gas produced more economically than by the present mode, without employing large numbers of fine strong men to destroy their health by charging red-hot retorts through very narrow apertures, with small quantities of coal, and to perspire for twelve hours in front of an intolerably hot radiating surface."

He proposes to substitute for the sinews of these men the action of steam power, and with this intention he considerably amplifies the usual dimensions of a retort in order to obtain in one distilling apparatus as much, if not more, heating surface than is now found in a whole bed of sixteen retorts, 20 feet long. This he does for the purpose of having the floor of retorts all on the same level, in order that the steam apparatus used for charging and drawing one of them may be adapted to the others by only moving such apparatus upon rails in front of the retorts. Then he describes a huge retort, 30 feet long, 2 feet high, and 9 feet wide, built of bricks, and having at each end a cast-iron mouthpiece plate, contrived for receiving a luted lid, which is firmly secured by screws and cotters. This retort is provided with two or more orifices at the top, by which the charge of coals is introduced by tilting wagons running on railways. The coals so introduced into the retort are then spread equally over the [illegible] by the aid of a rake, which forms the head of a rack

worked by a steam engine. The charge of coal is six tons, forming a layer 10 inches deep. When the charge is worked off the coke is pushed out in one cake by the assistance of the steam rack, the head or rake of which being for this purpose inverted, so as to act with its head instead of its teeth. The rack with the rake at the end of it is of cast iron, and slides in a cast-iron frame, and receives its motion from a steam engine fitted to the frame, motion being transmitted by the ordinary mechanical contrivances. In order that the same steam apparatus may be rendered serviceable for working twenty-four retorts or more, the frame rests on a system of wheels running upon rails parallel to the front of the retorts. The steam is conveyed by means of a pipe placed in a casing and surrounded by sand or other non-conductor, and running the whole length of the beds of retorts. This pipe is provided with outlet branches and cocks between each two retorts for the purpose of delivering the steam to the engine through a movable conducting pipe. This arrangement was a cumbrous one, and never came into use.

In describing the next step towards the production of a steam stoker, we may pass by those arrangements for which a number of patents have been granted from time to time, in which the mechanical feeding of coal by an archimedean screw through a retort and the delivering of coke or breeze (for coke it cannot be) at the other end are the chief features. However desirable the working of retorts by this description of machinery may be, there is the great drawback of bad coke or none at all being produced, which every gas manufacturer knows to be a serious disadvantage.

The next arrangement of steam stoker was that of Mr. Green, of the Preston Gas-works, in 1860, shown in Fig. 4, which is the first that professes to draw and charge ordinary retorts. Great credit is due to Mr. Green as having been the pioneer of drawing and charging machinery in retort-houses, his first attempt being the basis upon which succeeding machines have been constructed. It consisted of a framework mounted upon four wheels running upon rails parallel to the front of the benches of retorts, and was worked by a continuous shaft, which was carried the full length of the retort-house, and communicated motion to the machinery. The rake and scoop were mounted upon a table or platform, capable of being raised or lowered to the varying heights of the retorts. A long screw driven at a rapid rate propelled the rake and scoop into the retort, and a reverse action withdrew them, while the rake-head as well as the scoop were reversed by hand, and the scoop was also filled by hand from the retort-house floor. It was found, however, that this

arrangement would not answer, and it never got beyond the provisional specification, and like the previous invention was abandoned.

Next comes the Best and Holden machine, seen at Fig. 5. It was first erected and tried experimentally at the Horseferry works of the Chartered Gas Company. The Alliance Gas Company of Dublin, having occasion in 1867 to erect a new retort-house, made arrangements for the introduction of this machine there, as they had been annoyed by strikes among the stokers. The retort-house was accordingly built to receive four of these machines. Thirty benches, of nine retorts each, were constructed to suit this new system of drawing and charging. The nine retorts were set in a bench at equal distances from each other, in three rows of three retorts each, one above the other; this arrangement being necessary as the machine draws or charges three retorts at a time. Each vertical file of three retorts opened into a common chamber, which was closed with one door after the retorts were charged, one ascension pipe from the chamber conveyed the gas to the hydraulic main. The door was planed for 3 inches on its face, to come into contact with a corresponding planed surface on the chamber or mouthpiece, so as to make a gas-tight joint when tightened up by three cross-bars driven into wedge-shaped lugs. After some time these doors, which were 7 feet long and 2 feet wide, were found to fail, the great heat causing them to expand unequally, and the heavy blows on the cross-bars necessary to bring the planed surfaces together making them warp and twist; these doors have been superseded by luted lids.

The machine consists of a strong combined framework of wrought and cast iron moving on flanged wheels upon rails as in the previous machines. The benches are elevated, and the machines run on a stage nearly level with the bottom retorts, and the stage is supported by a double row of columns placed under the rails. A platform on the framework of the machines carries an upright boiler with a double-cylinder engine attached. The engine, which is fitted with common link reversing gear, drives a shaft, upon which are geared two pitch chains attached to two carriages, having four small wheels running upon the inside flanges of two girders, and carrying respectively the three rakes and the three scoops.

Above the carriage is a hopper, supported by columns from the bottom framing, for containing the coals for a charge. The machines on either side of a range of benches take in their supply of coal and water, and a section, or nine retorts, having been opened, they advance along the rails till they are opposite three. The rakesman throws up the head of the rakes,

and they are sent forward into the retorts. When in the centre of the retort he lowers the rake-heads and they are drawn out, and the heads being at right angles to the retort, bring out the coke before them, which falls into a wagon under the stage, when it is cooled and wheeled away. The machine is then moved forward to the other open retorts, draws out the coke in the same manner, and returns to the three retorts it first discharged. Coal is then let down from the hopper into the scoops and they are sent into the retorts, and then turned over by the release of a strong spiral spring, and withdrawn thus inverted. They are turned back to their proper position by a rack acting on a wheel compressing the spiral spring, which is held compressed by a catch till again released.

The scoops are thus reset and held in position for their next charge of coal, when the machine proceeds to charge the other six retorts in the same manner. One man drives the machine, two trim the coal into the measures in the hopper, and one guides the coal from the hopper into the scoops, and also closes the doors as the retorts are charged. When the section is finished the machines take in a fresh complement of coal and water for the boiler and rakes, they get a little cleaning and oiling, and are ready for the next section as the time for drawing again arrives.

A system of signals by steam whistles regulates the working of the machines on the opposite sides of the retort-house, otherwise the rakes or scoops would meet in the centre of the retorts, and probably get damaged; so as soon as the rakes of one machine have taken hold of the charge of coke the engine driver signals to the other machine to enter, which then takes hold of its charge. The same is done when the scoops are sent in; the driver signals when his scoops are reversed, and the opposite driver sends in his. By these means a collision is avoided, and yet it leads to no delay, No. 2 machine keeping a few seconds behind No. 1. When in full work the retorts are drawn and charged at the rate of 60 per hour, or three times as quickly as by hand. The quantity of coals put into each retort is 20 cwt. per twenty-four hours, the retorts being 18 inches diameter and 20 feet long. This quantity varies at times according to whether coal or cannel is being used.

Engineers who have seen these machines at work have made objections to them, the principal ones being that they charge three retorts at a time, thereby lowering the heats of the bench considerably, and that they require the whole of the retorts to be set in the same fixed positions; consequently, before the machines can be adopted, all the retorts must be set to suit them, and if any repair is needed to one retort, two others must

be idle. It also requires the retorts to be set on a stage, an arrangement not generally approved of. Others say the weight of the machine is too great, and the wear and tear and consequent expense excessive. Some of these objections may be met by saying that when gas companies are about to build new retort-houses, arrangements could be made for setting the retorts to suit the machines, and although they may be more costly settings, and necessitate the use of a stage, yet the advantages of machine work would be gained.

A supposed improvement on the Best and Holden machine forms the patent of Mr. Holden, shown at Fig. 6, and two machines have been erected on this principle at the Beckton works, and have been at work there some time. They are driven by an endless wire rope from a stationary engine at the end of the retort-house, and each machine consists of a framework mounted on wheels supporting carriages to which are attached three rakes and scoops, as in the Best and Holden machine. The rakes and scoops, however, are capable of being swung out at right angles to the retorts, so that only one or two may be charged or drawn at pleasure; thus any one of the three may be left off for "scurfing" or repair, while the other two in the same file may be at work. This machine does not carry its own coal, but the scoops have to be filled by hand. In the course of time arrangements are to be made for filling them from a shoot at the back of the stage; the scoops swinging round to receive their charge of coal, and back again to deposit it in the retort. The mouthpieces are closed singly, and have one ascension pipe to each.

Some four years ago Messrs. Dunbar and Nicholson patented a single-scoop machine, shown at Fig. 7, which was tried at one of the London works, but its working presented no advantages, and it has not been adopted; the complicated action of the machine, and the expensive character of the arrangements for adopting it in a retort-house being against its use. The machine was suspended from travelling girders overhead, which moved up and down the retort-house like a travelling crane, one rail being attached to the wall of the house, the other being supported upon columns in front of the benches. It received its steam through a pipe running along the retort-house wall from a stationary boiler, and the whole of the machinery moved backward and forward in going in and out of the retort. The scoop was filled by hand from the floor of the house, and turned by hand in the retort. The rakes were a series of blades fitted into '' scoops, which were put into the retort inverted, and t ıe action of a hand-wheel and gearing, the rakes were nd and cut off the coke in sections to be drawn out.

The whole machinery was capable of being raised and lowered so as to enable it to command any one retort in the setting.

The next system for notice is that introduced by the author, and which is known as the Somerville and Robinson machine, seen at Fig. 8. This arrangement embodies improvements suggested by several years' experience with the Best and Holden machine at Dublin. Having from time to time made improvements upon the Best and Holden machines, so that they worked more satisfactorily each succeeding year, and realizing the advantages of machine work, and the desirability of adapting machinery to the charging and drawing of retorts as at present set in the other retort-houses of the Dublin works—that is, in benches of sevens—these machines were designed, built, and set to work some twelve months ago, and are now working, and giving every satisfaction. In this arrangement there is one machine for charging and another separate machine for drawing. Each machine carries a small boiler and engine of about two horse-power, with the necessary gearing, and runs upon an inverted bridge rail sunk level with the retort-house floor, so that there may be no obstruction to wheelbarrows or to the ordinary work of a retort-house.

The machines are each composed of three lattice girders, connected together and supporting the boiler and engine, and carrying a framework of wrought T-iron. Within this framework is a platform, carrying the rake or scoop, and capable of being raised and lowered at pleasure to suit any height of retort. Thus, with the horizontal motion of the machine upon the rails and the vertical motion of the platform, the rake or scoop commands any retort, whatever may be its position in the bench. The rake and the scoop each have motion given to them by means of a chain passing over suitable pulleys driven by the engine. The scoop receives its coal as it enters the retort from a shoot, it having been raised by an archimedean screw from the hopper at the opposite end of the machine. The hopper is supplied by a man from the floor of the house in the absence of any overhead arrangement.

The method of working this machine is as follows: One man takes off the lids of the retorts of one row, the drawing machine moves opposite to one retort, sends in the rakes, and at one draw brings out the coke, and then moves on to the next retort, and the charging machine comes up to the discharged retort, and puts in the charge of coals. The scoop is made double, and forms two small scoops, hinged together, and discharging in opposite directions, so that in turning the coal is spread well over the surface of the retort, thus utilizing the greatest amount of heating surface in the retort. As the retorts are charged, the

man who preceded the drawing machine, and took off the lids, now follows the charging machine, closing the retorts. Two boys drive the machines, one man fills the coal into the hopper, and another attends to the taking off and putting on of the lids or doors. The platforms of the machines are now altered to the level of the row of retorts to be drawn and charged next, and those operations proceed as before. By these arrangements the retorts are exposed to the action of the atmosphere a much shorter time than in the case of hand labour, as the stokers generally "slack out" ten or a dozen doors at once, and draw them all before charging any, thus leaving the first drawn retort a long time to the cooling atmosphere, whereas with the machine the retort is charged directly it is emptied, an advantage that must be appreciated by all gas engineers.

The machines are in constant action from 6 A.M. to 6 A.M., with the exception of the breakfast and dinner hour for each "shift." The retorts are timed so as not to fall due at those hours. The work of drawing and charging is done with a regularity that cannot be attained by manual labour; the retorts are supplied with the maximum quantity of coal they will take, and the quantity does not depend upon the caprice of a scoop driver. The coke must be raked out clean, and a quantity cannot be left in, as is often the case with manual labour, when the eye of the foreman is not on the men. The same quantity of gas is made on Saturday nights and Sundays as on any other day of the week, a result not often obtained with hand labour.

The two machines draw and charge at the rate of 42 retorts per hour; and, allowing two hours for the meals of the men, 30 benches of sevens is the full work for them. Thus 210 retorts can be charged twice in 12 hours, or four times in the 24 hours, with $2\frac{1}{2}$ cwt. of coal per mouthpiece for retorts 18 inches diameter and 20 feet long, the size best suited to the machine. This is 10 cwt. per mouthpiece, or one ton per retort per 24 hours, or 210 tons are carbonized per diem, making per week 1470 tons, at a cost, in Dublin, of a little over 6*d.* per ton.

The following is the estimate of cost:—

Eight drivers at 21*s.*	£8	8	0
Four lidmen at 25*s.*	5	0	0
Four coal fillers at 25*s.*	5	0	0
Four boys, luting, at 15*s.*	3	0	0
Two caldrons of coke per day, or 14 per week, at 18*s.*	12	12	0
Oil and waste per week	2	16	0
	£36	16	0

To do this work by hand labour would require one stoker to each 18 retorts, or 46 stokers at 35*s.*—80*l.* 10*s.* per week—which is at the rate of 1*s.* 1¼*d.* per ton, showing a saving in favour of the machine labour of 7¼*d.* These are the rates of wages in Dublin. If London wages were taken for the calculation (as perhaps they ought to be), and London stokers being paid 39*s.* per week, it would add another 2*d.* per ton to the cost for stoking, and from statistics the author has received from some of the London works, he finds the stokers' wages per ton of coals amounts to 1*s.* 3*d.* Probably the wages of engine drivers and lidmen for the machines would also be a little higher, but with machines in full action there would be a saving of 8*d.* per ton on the coal carbonized. Now a saving of 8*d.* per ton of coal amounts to the sum of 3333*l.* 6*s.* for every 100,000 tons of coal, so that the adoption of the machine means not only the general advantages pointed out, but a large saving in the carbonizing department. Against this it may be said that there is the interest on money expended, and the wear and tear of the machines. Two sets of machines to work a range of 30 benches will cost 1500*l.*, and in case of accidents or breakages it would be well to have a duplicate machine, which costs a further sum of 700*l.*, or 2200*l.* for three sets. This amount, at 10 per cent. per annum, or 220*l.*, is about ½*d.* per ton of coal carbonized, and in taking this into account it must be borne in mind that in lieu of the machines, scoops, rakes, shovels, and other tools must be used, and it is well known how soon they wear out.

The cost of wear and tear for machines does not exceed that of the retort-house tools, and is, in fact, barely as much, for if the wages of two or more blacksmiths and their strikers, which are continually required for the repair of the rakes, scoops, &c., be taken into account, together with the smithy fuel, iron, &c., for repairs, as well as the tools of the smith's shop, it will be found that the wear and tear is in favour of the machine.

There is no doubt that it will be some years before the use of these machines becomes general. Gas companies as a rule are very conservative, and look upon anything new as uncertain and unreliable until well proved. But some notice is beginning to be given to drawing and charging machinery, both at home and abroad, and a great number of patents are being taken out, no less than four gas engineers having applied for patents since the commencement of the present year. These are Mr. Mann, of the City Works; Mr. Foulis, of Glasgow; Mr. Richards, of London; and Mr. Taylor, of Oldham. In America a patent has also been applied for by Mr. Rowland, at Greenpoint, Long Island, for drawing and charging gas retorts by machinery. Hence it appears that interest is awakened, and as the use of

the machines is extended, experience will suggest improvements.

Among others who have seen the machines, and have taken an interest in their working, are some of our leading hydraulic engineers. They have carefully watched their working for the purpose of introducing the hydraulic principle as a motive power instead of steam. But they have abandoned the idea, although models have been supplied to some of the firms for the purpose of experiments in their workshops. They have stated frankly that there would be no advantage in substituting water for steam, but that it would be much more expensive and very troublesome, owing to the constant motion of the machines up and down the retort-house. The notion of having a small accumulator on each machine was also given up, as being too costly. There cannot be a more simple and easily managed driving power than the small engine attached to each machine.

The continuous system of gas manufacture by machinery advocated for some time past, particularly by Mr. Bower, of St. Neots, has now become an accomplished fact. The machines start at 6 o'clock, draw and charge No. 1 retort, and go on to one after the other until the whole 210 retorts are completed at 12 o'clock. When the charge of No. 1 is exhausted of its gas, the machines are ready for it again, and so on for the next six hours, going through the whole consecutively. The coal being spread over a large heating surface 3 inches deep, is carbonized equally throughout, not as is sometimes the case with careless stokers, when a half-burnt mass in the centre is often drawn out; on the contrary, the coal lies in the retort undisturbed, while it agglomerates into hard, useful coke. As soon as the gas is produced, the coke is quickly withdrawn, and the coal as quickly charged, to undergo the process under the most favourable conditions for extracting good gas and leaving a valuable coke.

A new range of benches in sevens was built last summer in Dublin. As they were to be worked by machinery, the usual stereotyped arrangement was not adhered to. The arrangement consists of brick retorts 18 inches diameter and 18 feet long, heated by one fire instead of two, and having one mouthpiece with one ascension pipe, the other end having merely an iron rim adapted for a luted lid. There is one length of hydraulic main to each bench, with a varying water-line arrangement, so that when the retorts are charged there is no seal to the dips. By the arrangement of flues the benches are admirably heated with one furnace, thus saving largely in fuel, wear and tear, and labour,

and when worked by machinery the result leaves little to be desired.

Although it may be some years before machines come into general use, they will surely, although slowly, supersede hand labour, and whether the machines of the future be Best and Holden's, Holden's, Somerville and Robinson's, or any other, it matters not, so long as the advantages of mechanical stoking are secured.

DISCUSSION.

Mr. H. GORE said he thought that before dealing with the question of mechanical stoking it was very important they should take into consideration what the operation was to which the mechanical process was to be applied. Some years ago he had considerably to do with the application of machinery for the purpose of stoking boilers for the generation of steam. Many gentlemen present would no doubt remember the machines proposed by Mr. Williams, Mr. Jukes, and some other inventors, and were aware that in the attempt to apply machinery for this purpose there were very serious obstacles in the way, because the rate of combustion or the amount of power or force to be generated by the fuel supplied by these machines was unequal. There were many circumstances which the machinery could not control which entered into the consideration, and in applying that rule to the employment of stoking machinery in the generation of gas he thought the question must at once arise whether to make it successful it would not be necessary, more or less, to have automatic firing. It appeared to him that the great question they had to deal with was not the quantity of coal to be put into the retorts or the facility of putting it in and of removing the coke after carbonization, but an arrangement by which the coal put in should be in a fair proportion to the amount of heat to be given out by the furnaces, and that such an amount of coal only should go into the retorts as they were capable of bearing. Whatever process of stoking was adopted, the firing in the furnaces could never be so adapted as always to carbonize the same amount of coal in the retorts. A coal might be employed which would give off its gas more rapidly than another kind, or there might be a greater or less amount of moisture in it. If there were a greater amount of moisture in the coal than usual, the temperature of the retort would be reduced, and a larger amount of heat in the furnace would be required to evolve the gas in the coal; if, on the other hand, the coal was exceedingly dry, the retort would increase in temperature. The question therefore, as he had

said, was not so much the mechanical arrangement for putting coal into the retort, as that of providing that every equivalent of heat generated in the furnace should represent an equivalent proportion of gas when that heat became latent. It must be borne in mind what it was that took place when coal was put into the retort. The coal underwent a process of dry distillation, gas was given off with greater or less capacity for absorbing heat. If the amount of heat derived from the furnace was not adequate to the distillation of the quantity of coal introduced, there would be immediately a reduction in the product of gas, and an increase in other products in the shape of tar and ammoniacal liquor. All these were difficulties which mechanical stoking could never meet; because, if to be of any value at all, the machinery must be continuous in its operation. The machinery could not be stopped to ascertain whether the retort would bear a shovelful more of coal or not. If the heat was in excess of that which was required for the quantity of coal put in, there was so much fuel wasted; if below, then a less quantity of gas would be produced, and again there was a proportionate loss. He did not offer these remarks with any feeling of prejudice against machinery; for he was convinced it was to the interest of gas engineers to promote every invention which had a tendency to improve the processes of manufacture in which they were engaged; but these were objections which would have to be taken into consideration before an unqualified assent was given to any description of mechanical stoking.

Mr. MELLOR said it seemed to him that all stoking had to be guided by the eye of the stoker as to how much coal should be put into the retort, according to the heat of the retort. Now, although the contrivance brought under consideration by Mr. Somerville was strictly mechanical, still it must be remembered there would always be a man's eye to guide the machinery and regulate the quantity of coal put into the scoops, and there was just as much chance of doing it properly by the machine as by the shovels now in use. This remark alone would answer Mr. Gore's objection. He did not say that there should be the same quantity put into every scoop; any quantity desired might be put in, and as there would be a foreman in charge of the machinery there would be not the slightest difficulty in regulating the matter. As to the elimination of gas, he did not see that that had anything to do with the stoker; or whether [illegible] was produced or less, more ammoniacal liquor or less. [illegible] he did not think Mr. Gore's remarks applicable to the [illegible] mechanical stoking. The retorts to suit the mech[illegible] were placed in much more regular order than in t[illegible] system, and he thought gas managers ought

to pay every attention they could to an appliance of this kind, reducing, as its object was to reduce, the cost of manual labour. Now, they all knew that if they could get a larger number of retorts supplied by one or two furnaces in one oven, there would be a greater regularity of heat than when employing a smaller number of retorts. Supposing the retorts were not too large, the introduction of a large body of coal in a regular and even manner would not be so evil in its effect as if they were charged irregularly. The best thanks of the meeting were due to those gentlemen who were endeavouring to supersede manual labour by mechanical apparatus.

Mr. F. W. HARTLEY said he had had the opportunity to see Best and Holden's machine at the Dublin Works on several occasions, and he certainly had been surprised at the ease with which the whole thing was manipulated. At the same time he was struck with a sense of the clumsiness of the machine itself, and with the conviction that there was ample scope for great improvements in its construction. The figures given by Mr. Somerville on this occasion differed from those which he submitted at the Gas Managers' Meeting in 1870, inasmuch as he now said the cost of working the machine was 6*d.* per ton, whereas in 1870 he gave it at 3·65*d.* per ton, to which was to be added the charge for royalty to the inventors. He believed those gentlemen had undertaken a contract at 3*d.* per ton for working, and 6*d.* per ton for royalty; any difference in the cost of working from the 3*d.* was to be divided between them and the company, making something like 9·35*d.* as the total of the expenses. Now Mr. Somerville gave 6*d.* per ton as the expenses, and it would be interesting to know whether this 6*d.* covered the royalty as well as the actual working expenses. He (Mr. Hartley) supposed it did not. Another point in the application of these machines which struck him as being of importance, was the effect they produced upon the retort settings. He had seen the machines in motion, and (perhaps prejudiced a little with old notions) had entertained the idea that they were liable to destroy the settings at a much more rapid rate than hand labour did. It would be interesting to all gas men if Mr. Somerville would give the meeting the result of his experience as to whether the settings were deteriorated to a greater extent by the use of machinery than when worked by hand, and if so, what effect that might have upon the cost. He was quite satisfied that if machinery could come into operation for the charging of retorts, it would be of the greatest possible advantage; and taking the difference between 1*s.*, or whatever the cost for hand labour was, and the cost of mechanical stoking, as given by Mr. Somerville, there was clearly an economy in the latter.

It must also be remembered that after a while the royalties would cease, so that ultimately there would be a saving in this department equal to the whole cost of purifying the gas.

Mr. G. ANDERSON did not know that he could be said to have much experience in the matter; but, having frequently seen the machines in operation, he felt a little with Mr. Gore as well as with Mr. Mellor. He thought, though these gentlemen differed, there was a great deal of truth in what they both said, for if it were taken for granted that the difficulty existed which Mr. Gore pointed out, it was clear that until that was overcome mechanical stoking would not be so successful as to supersede manual labour. But the few times he had seen these machines in action (he referred specially to Mr. Somerville's machines) he did not see that the objection applied very much, because there were means, to some extent, of regulating the supply of coal. In that respect it was unlike Best and Holden's machine. In the latter the three scoops were filled by a deluge of coal poured into all of them at once, and the scoops were then sent into the retorts; but Mr. Somerville's machine was not so constructed. The scoop as it began to enter the retort began at the same moment to be filled with coal, and the filling could be stopped, or partially stopped, during its progress. He (Mr. Anderson) apprehended therefore that there would not be much difficulty in regulating the supply of coal to the heat of the retort. He also thought, with Mr. Mellor, that when a man was employed who understood the setting of retorts, he would be well able to see that the heats were uniform. Such being the case, there need be no great hindrance on this score to the success of the invention. On the question of the comparative cost of wear and tear, he quite agreed with Mr. Somerville, and he had no doubt whatever, looking at Mr. Somerville's machine, that there would be a saving by its use over manual labour. There were some arrangements which tended to the conservation of the machinery which Mr. Somerville had not mentioned. For instance, the rake he employed was hollow on the top, and there was a small stream of water percolating into the rake which kept it cool during the whole operation of going in and coming out. The rake never got very warm under any circumstances. With regard to the cost, there was no doubt in his mind that it was in favour of machine stoking. Great credit was due to Mr. Somerville for taking up the question, because, as he had said, gas companies were a little afraid of entering into new undertakings of this kind. One great objection to Best and Holden's machine was the fact that, in applying it, all the retorts had to be set in a particular manner—a manner which did not exist in any gas-works in the kingdom. Mr. Somerville's

machine, on the other hand, would draw retorts just as they happened to be placed at the present moment, which was a question of great moment to gas companies.

Last December, when he (Mr. Anderson) saw the machine at work, it appeared to him to be pretty perfect, but he thought Mr. Somerville had not sufficient boiler power, for he noticed that the pressure did not maintain itself as the work proceeded. That was a small matter; it only showed he wanted more steam, which, of course, might cause more expense, though he did not think it would be appreciable. There had better be a superabundance of power than a deficiency. There was one matter he would make a remark upon, and it was this: it was well known that when gas retorts had been in action for a year or two, they would get hollow. He had seen retorts 3, 4, or 5 inches lower in the centre than at either end. That was a difficulty which would always exist; and whether those machines were capable of dealing with it he was not prepared to say. As to Best and Holden's machine, he was rather inclined to Mr. Hartley's opinion, that it might tend to injure the retort settings. The scoops were tremendously heavy, and they were all pushed in at the same time, so that an enormous force must be employed. All the scoops were drawn out too at the same time, and it was a question whether, if one happened to be bent more than another, they might not do it some injury in the process. On the whole he was inclined to believe that stoking by machinery would be some day *un fait accompli*, and he did not think any person could wish the contrary. The charging of retorts, although perhaps not the most laborious work to which a man could put his hand, was, like puddling iron, a hot job, and required great physical energy. It was also a dirty job, and probably no man who could get the same wages on any other work would willingly take to it. In the interest of humanity, therefore, he hoped that mechanical stoking would succeed. He hoped so also in the interests of gas companies, to save them from the dangers of strikes. In reference to strikes, however, he remarked that the men did not seem to understand their own force. Stoking, though a laborious job, was not an intellectual one, and human muscle was not very dear yet; still, these men did strike, and demanded high wages; and it would be to the interest of gas companies to show a little kindness to inventors, and not think to stand aloof till every new thing, which seemed to be designed for their advantage, was tried and found perfectly successful. In fact, if they did, nothing would ever be tried. Gas companies carbonizing from, say, 30,000 to 50,000 tons of coal per annum, should try these machines; and if a company were formed to let them out on hire the cost

would not be very great. If no good was secured by them, the fact of having tried and failed would ease their minds. He had no doubt that further improvements would be achieved, and that in the result machinery would take the place of human labour. Science was said to be the providence of man. It was well that mechanical should take the place of human labour, wherever it was practicable, under the guidance of the human intellect. This was a step in that direction, and he heartily wished it success.

Mr. R. HARRIS said there was one question he should like to ask—*viz.* whether the machines were adapted for drawing any other than circular retorts. Hitherto it had been taken for granted that the circular retorts were the only ones capable of being stoked by machinery, and nothing had been said about D retorts. He thought all gas engineers were agreed that in a humanitarian point of view, if by machinery of iron they could manage to do the excessively hot work now done by human agency, it was very desirable; but he was somewhat at issue with the writer of the paper as to the prevention of strikes by the use of machinery. In fact, he thought that by its use gas companies would be liable to be put into greater difficulties, because the labour required for working the machinery would be of a more skilled character than that employed at the present time; consequently it would be far more difficult to replace the men on strike than with those whose operations were simply hand labour. On this ground, steam stoking might not be advantageous. In other respects, a system of steam stoking would be a decided improvement, bearing specially in mind the saving effected as shown by Mr. Somerville's figures. As to the question of the durability of retorts, he might say that at Beckton he had heard of a mouthpiece having been drawn off by the use of Best and Holden's machines, but since that accident the whole of the mouthpieces had been strengthened, which had prevented a repetition of the mischief.

Mr. WATSON said he had listened to Mr. Somerville's paper with considerable interest, dealing as it did with a question of vital importance to gas companies. There were, however, some points upon which he should like to have further information. In the first place, Mr. Somerville had given them the length, but had not otherwise given them the size of the retorts he used. He wished also to know the product per mouthpiece for each retort. The question of wear and tear had already been raised; but he ask further, whether the 6*d.* per ton as the cost of work led the wheeling away of the coke from below the ret ieces, as this was an important element in coming to

Mr. E. G. Bartholomew said, not being a gas engineer, he did not propose to enter into any question of a technical character, but there was a remark made by Mr. Harris to which he took exception—*viz.* the undesirableness of using machinery, as not tending to reduce the liability to strikes. Everyone must see that a general remark of that kind was applicable to every case where machinery was introduced to supersede manual labour. It might be said that the introduction of the locomotive was not an improvement upon the old stage coach, because the engine drivers might strike, and the public would be in a worse predicament than before, and that we should go back to the old stage coach, as the driver might be more easily replaced. But on this account he confessed he could see no argument against the introduction of the locomotive.

Mr. G. Livesey said the difficulty about trying the steam stoker appeared to be that so few companies had stage retort-houses. There were stages in some of the London works, but not in all. The Chartered Company were trying the system at Beckton, and he was told that the Imperial Company were about to try it at Fulham, so that before long it would have a very fair trial in the metropolis. The whole matter, to his mind, was a question of £ *s. d.* He could see no force in the difficulty raised by Mr. Gore; if there was any difficulty, it should be remedied in the furnace, and not in the retort. If the retorts were not hot enough, that was the stoker's fault. It was a perfectly easy matter to regulate the quantity of coal in the scoop—quite as much so by the machine as when employing hand labour. In fact, managers did not wish that their stokers should have a discretion in the matter, as they might often use it to the detriment of the company by not putting in enough. It seemed to him that hitherto the machines had been made on far too cumbrous a plan. He had not seen Mr. Somerville's, but was told it was much less open to that objection than the others. The work of drawing and charging was in reality work which one man was enabled to do. The scoop was really put in by the one man who held the T-piece; why, then, when machinery was substituted for manual labour, should the thing be made so cumbrous as some were, and why was so much power provided to do that which could, as he said, be done by one man? The same remark applied to the drawing apparatus. He thought there should be some little adaptation of the machines to render them less cumbrous, and to enable them to work with a less expenditure of power. He was certain of this, that all gas managers would be glad to adopt it, and though he went so far with Mr. Harris as to admit that the labour it would require was of a more skilled character, it must

be rimembered that fewer hands were necessary, and no doubt, in the event of a strike, most engineers in London would be able to command a sufficient number of men from the yard, fitters and others, to drive the machine. It resolved itself therefore into a question of cost, and if 1*d.* per ton could be saved on the coal carbonized, the steam stoker must come into general use. At his works there had never been a single stage, but he was now building a new retort-house with a stage, purposely to introduce the stoker, should the results of the experiments at Beckton and Fulham be such as to warrant it.

Mr. PENNY said he had not yet gathered from what Mr. Somerville had stated whether his stoker could be used without a stage. If it could be, its introduction to a great many works might be secured, where otherwise it could never be made available. It was impossible to listen to the way in which Mr. Somerville had described his invention without a feeling of admiration at the manner in which he had worked out all its details; and, after listening carefully to all that had been said, he (Mr. Penny) was persuaded this invention must ultimately come into general use if it could be made to pay. No doubt, looking upon the question of gas making with a philanthropic eye, it would be well if they could dispense with the hard and laborious toil which men employed in the retort-house had to endure; but he was not sure whether the men themselves would thank the inventors of this apparatus for it. He did not agree with Mr. Harris that its introduction would tend to increase the liability to strikes, because when this kind of machinery was once established, there would always be mechanics to be obtained who could deal with it, and they would be more amenable to reason than some of the stokers now employed. He hoped therefore Mr. Somerville would be able to assure the meeting that, if it could not be done now, he would at some future time adapt his charging machine to works where no stages existed.

Mr. H. GORE said in America there was a proposition to use such machinery without a stage at all. The only thing provided was a gutter, about 4 feet deep and 2 to 4 feet wide, in front of the retorts. In this gutter wagons ran, being drawn to and fro with a wire rope. As soon as the first was drawn up in front of the retort and filled with coke, it was drawn on and another took its place.

Mr. C. WOODALL said that having seen Mr. Somerville's machine he could but express the satisfaction it had afforded him, and the confidence he had in its future success. He (Mr. Woodall) was surprised at the remarks which had been made as to the use of staging, when the drawings showed the very

plan which Mr. Gore said was adopted in America. He thought that Mr. Somerville, in the machine which he had invented, had removed a very large portion of the difficulties which interposed to prevent the use of steam stoking in the past. With the cumbrous machine at work almost side by side with his at Dublin he (Mr. Woodall) could understand damage being done to the retorts. Machines of that kind were extremely heavy, and anything but sightly to deal with. But separating the drawing from the charging apparatus—splitting the machine, as it were, in two—though adding perhaps to the cost of the working, was an unmistakable step in the right direction, as it simplified the apparatus for the work it had to perform. Mr. Somerville had also very prudently adopted his machinery to the mode of setting retorts, which the practice of many years had sanctioned. Whether those settings were in all cases the best for gas manufacture might be a question; but they were the result of careful study and practice during the past fifty years, and to have been asked to lay the system aside and adapt their settings to the new machine would have been an objection with many engineers. He quite agreed with Mr. Livesey that the general introduction of mechanical stoking must come to be a question of cost, so far as the actual performance of the work was concerned. Mr. Somerville had demonstrated that the machine would answer entirely, and he (Mr. Woodall) was disposed to believe that whether or not at the present time there would be that amount of economy in the operation which was stated in the paper, it would be so eventually. Mr. Somerville might possibly improve upon it, and when brought into greater use than it now was in Dublin he might bring about such a result. He was inclined to think that in the estimate given, Mr. Somerville had counted too much upon the amount to be got out of the labour employed, and had expected rather more than could be got out of one man. And here he could not help remarking upon the way in which the labour of stokers had been exaggerated and overdrawn. It had been represented that the practice was to work them incessantly during twelve hours a day, and to repeat that all through the year. Of course every gas engineer knew better. He wished to say one word in confirmation of Mr. Mellor's remark as to the ease with which the supply of coal was regulated to the scoops. Nothing could be more beautiful than the way in which this was accomplished by the screw arrangement referred to. When he (Mr. Woodall) saw the machinery at work the heats were very low, but the charge was so readily adjusted to the state of the furnace that he thought that even Mr. Gore would have been satisfied.

Mr. COLYER said Mr. Gore spoke of the difficulty in mechanical firing, and referred—specially, no doubt—to steam boilers. But the observations made were not according to his (Mr. Colyer's) experience, and he could mention many cases in which it had been carried out with great success for several years. Several gentlemen had spoken of the difficulty arising from strikes. He had had some experience in labour-saving machinery of various kinds, and he never knew one in which there was not a liability to strikes; but the moment the men found there was less labour to be performed, that feeling and disposition subsided very soon. In one instance in which a strike had occurred, the men finding that they could earn more money with the machine than without it, they very quickly came back to their work. Every engineer would bear him out that with all new machinery there were great difficulties at first, and with machines of this kind especially, simply because it was opposed to all the old notions. He instanced the introduction of lifting machinery at some of the wharves. A few years ago he had experience in connection with gas companies, and he knew there could be no practical difficulty in regulating the charges by this machine. He thought the only practical difficulty in its introduction would be the first cost of the machine. Probably that would preclude many small companies from adopting it.

Mr. A. WILLIAMS felt at the outset that any contrivance which would reduce the cost of labour in the manufacture of gas must deserve the attention of an audience like the present. The introduction of a machine that would do the work of the stokers must be a benefit to all gas companies, provided it could be done at a less cost than by the employment of manual labour. There were one or two points upon which he was not quite satisfied. He wished, in the first place, to ask Mr. Somerville in what state the rakes left the retort—whether they were very hot and whether they bent? Also with regard to the lasting power of the scoop. It was not like a scoop employed in hand labour, that was placed on the ground to be filled; this one never went on the ground. Mr. Anderson said something about the rake being tubular, and being supplied with water which kept it cool. He (Mr. Williams) wished to know whether the water ran along the rake and so got into the retort. If so, it was not a good arrangement, as that would tend to decrease the heat. He thought a simple tube, with air passing through it, would answer much better than employing water. There was one practical difficulty in drawing retorts which was very hard to deal with, that was the clearing away of the coke from the centre. The machine, as he understood, worked on both sides,

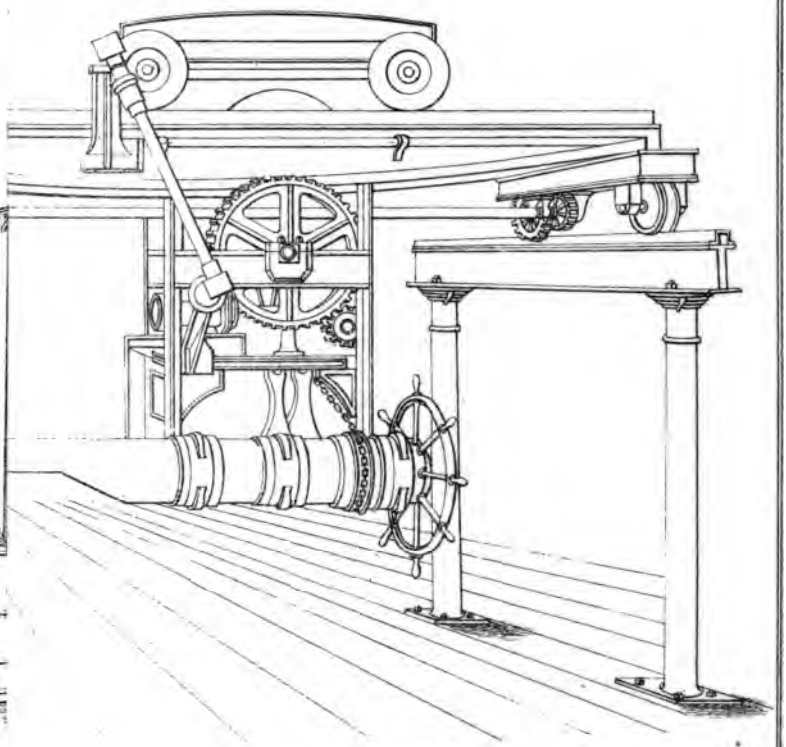
and he should like to know how the two rakes got the little bit of coke out of the centre.

Mr. SOMERVILLE, in replying upon the discussion, said he thought the gentlemen who had spoken had so fully answered one another that it was not necessary for him to say much. They appeared to know as much about steam stoking as he did, so that he had very little left to reply to. Mr. Penny asked what was the smallest number of retorts to which this machinery was applicable. Confining his reply to Somerville and Robinson's apparatus, he should say that in any works where the carbonization amounted to 15,000 tons a year, a considerable saving might be effected by its adoption. With the Best and Holden arrangement, which had three rakes and three scoops, a carbonization of 30,000 tons annually would probably be the smallest sized works to which it was applicable. Mr. Penny also wished to know whether the machine could be used without a stage. The last-named did require a stage. Somerville and Robinson's did not. In the diagram on the wall, there was just such an arrangement of gutter and truck as Mr. Gore referred to as being adopted in America. In reference to Mr. Gore's inquiry, he might state that in both the machines the quantity of coal could be adjusted. In the Best and Holden, the man who filled the scoops regulated the supply. If the heats were a little bit down, he did not put so much in; if the heats were well up, he filled the scoops quite full. By the Somerville and Robinson machine there were means for regulating the supply by a screw; but usually as much coal was put in as possible, and the dampers controlled the waste heat. By that arrangement the heats were kept up to the maximum. Mr. Mellor's question had been answered. Mr. Hartley referred to some estimate given by him (Mr. Somerville) on a previous occasion as to the cost of working the Best and Holden machine a few years ago—*viz.* 3·35*d.*, *plus* 6*d.* for royalty, which was a different amount to that given to-night. The reason of the increase was that wages had risen from 20 to 25 per cent. At the present time the cost of working the Best and Holden machine would be about 5½*d.*, or a halfpenny less than the cost by Somerville and Robinson's. Mr. Hartley also wished to know the amount of deterioration to the retorts which arose from the use of machinery. There was none whatever. In his experience there was no more deterioration or damage done to the retorts by the use of the steam stoker than by hand labour. Mr. Anderson's objection to the size of the cylinders and the boiler could, under the Somerville and Robinson arrangement, be easily overcome. The machine at Dublin was made at his works, and he erred perhaps on the side of lightness. In the

next machine to be made he would have a double cylinder instead of a single one, and would have a boiler of about 15 per cent. greater power. Mr. Harris wished to know whether the machines were applicable to any section of retorts. They had hitherto been confined solely to circular retorts, and in his (Mr. Somerville's) opinion they were the best; but the Imperial Company were having some machines made to draw D retorts in a bench 9 feet high. He was himself now devising a sort of split rake for the purpose of drawing D retorts. There was a little difficulty in the matter, but he thought it might be overcome. He did not agree with Mr. Harris that there was more likely to be a strike with skilled men than with the ordinary labourers in a retort-house, for he thought skilled men were a little more reasonable. The number of men also was so much reduced that the chance of a strike was necessarily less. He understood that at Beckton Mr. Trewby took off all the skilled men and worked the machine with but little reduction of speed with merely the common labourers from the yard. In reply to Mr. Watson, he stated that the retorts were 18 feet long and 18 inches in diameter. The Best and Holden machines worked 20 feet retorts of 18 inches diameter. The result was over 5000 feet per mouthpiece for cannel and coal; but the difference in one place and another could hardly be entered into. There was no reason why the same amount of gas per ton of coal should not be obtained with the use of machinery as by hand labour. In reference to Mr. Williams's inquiry, he thought it was stated in the paper that the difficulty suggested had been overcome, and the little bit of coke in the centre was not left in. The fact was the rakes were made a foot longer than usual, and they lapped over one another in the centre. In his machine the rake handles were V shaped, having a hollow trough 2 inches deep, constantly filled with water. The rod which raised and lowered the rake-head worked in this trough, and the water did not get spilt into the retorts, and the rakes were kept perfectly rigid. The scoops were not more liable to damage than ordinary scoops, which were sometimes dropped on the floor. The wear and tear was much less than in the case of hand scoops.

The PRESIDENT said that Mr. Somerville had given them a most interesting paper, and there had been an equally interesting discussion upon it. He (the President) thought, on the score of humanity, there was no doubt that these machines would be used universally, if it was possible to use them successfully —*i. e.* successfully not only in a mechanical point of view, but commercially. No doubt, like all new machinery, the system had its difficulties, but from the description Mr. Somerville had

Fig. 7.



B. Alexander, Lith.

given it really seemed as if in his apparatus he had overcome the most of them practically. One great advantage of this apparatus was that it was adapted to all classes of settings, which was a very important matter, for it was well known that there was a variety of opinions among gas engineers on the subject of the best mode of setting retorts, and it was difficult to find two that would entirely agree. Retort setting of the best description was a matter to which a great deal of attention had been directed, and it entered so largely into the profits of a gas company, that there was a good deal of emulation on the subject. The man who could get the most gas out of a given surface of retort was the best manager. It did not appear to him that there were any difficulties in the way of the practical and general use of these machines, which might not be met and disposed of, and he could not but think there was sufficient mechanical skill and perseverance amongst the engineers of this country to perfect them, and adapt them completely for the use intended, more especially when it was considered that in one of the most difficult processes, that of puddling iron, machinery had been successfully introduced to supersede hand labour. A remark had been made about the want of success in mechanical stoking for steam boilers; he could only say that for some years he had had experience with Juke's patent furnaces, which worked admirably. By the use of that machine small coal was able to be employed in place of large, and both mechanically and commercially it had been a success. The success of machinery for retort stoking must be judged on a commercial basis, for after all, in manufacturing operations, that was the true test. But it occurred to him that if gas companies could use it practically as machinery only, without any remarkable commercial advantage, they would prefer it for the many reasons already suggested. He thought therefore Mr. Somerville and those who had gone before him had done them good service, and he wished them all the success which their inventions merited.

June 9th, 1873.

J. H. ADAMS, VICE-PRESIDENT, IN THE CHAIR.

RAILWAY TRAIN INTERCOMMUNICATION.

By S. ALFRED VARLEY.

The subject of railway train intercommunication has engaged attention ever since the introduction of steam locomotion, but during the last twelve years train intercommunication has received increasing attention. It has been reported upon again and again by the inspecting officers of the Board of Trade, and committees of general managers have from time to time had the matter under their consideration. In March, 1853, a sub-committee of railway managers (appointed by the Railway Clearing House in the latter end of 1852) issued a report in which they recommended the establishment of a communication between the guard and driver, but with regard to the question of giving passengers the means of signalling they reported as follows:—

"Without overlooking the possibility of such an arrangement being occasionally of service, the committee have been unable to persuade themselves that it would not lead to greater disasters than it could, on any view of the matter, prevent. Unless the guards and engine drivers had orders to stop the train whenever a passenger made a signal, the privilege would be useless to the latter. It, however, requires little acquaintance with railway travelling to be convinced that its dangers would be greatly increased if the train were to be stopped whenever and wherever a passenger under the influence of fear or levity chose to make a signal."

Many attempts at a comparatively early date were made to utilize electricity for communicating between guard and driver, and in 1855 the London and North-Western Railway Company spent a considerable sum of money over Mr. Gluckman's invention for this purpose, but had to abandon it, as it did not prove effective. In France also the question of communication between different parts of a train whilst in motion has received a great deal of attention, and a French commission of inquiry, appointed in February, 1861, reported that "an electrical communication only would solve the problem," but, for reasons stated in their

report, they did not then recommend giving passengers facilities for signalling. Experiments were, however, made on the French railways, and the Chemin de Fer du Nord, after experimenting for some years, fitted up all their rolling stock with electrical apparatus.

In 1864 a great step was made towards the establishment of passenger communication in this country. A sub-committee of railway managers was appointed to consider "the possibility of adopting some means of communication between the different parts of a train whilst in motion." This committee by public advertisement invited "persons having inventions professing to accomplish the object to submit them for examination." A very large number of designs was submitted and examined, some of which were recommended for trial, and a report was issued on April 1st, 1865, in the final paragraph of which the following passage occurs:—"The sub-committee is, however, of opinion that it is desirable, if practicable, to give passengers by express or other trains running for a considerable distance without stopping, the means in cases of emergency of attracting the attention of the guard, and of enabling him to stop the train at the next station, or under the protection of the next fixed signals, and they recommend that no effort should be spared on the part of the railway companies, &c., to effect this object." In December, 1864, Messrs. W. H. Preece and Bidborough patented an electrical system of communication, similar in many respects to that adopted in France on the Chemin de Fer du Nord. This was followed thirteen months later by another electrical system, the invention of Mr. C. V. Walker, and a month after this by an electrical system patented by the author in conjunction with Mr. S. M. Martin. Mr. Preece's system has been chiefly tested on the South-Western Railway. Mr. Walker's system has been adopted on the South-Eastern Railway, and the author's system was fitted to Her Majesty's train on the London and North-Western Railway in May, 1866, and has been in use on that train for six years.

During the session of 1867, a bill known as the "Passenger and Guard Communication Act" was passed through the House of Commons. In the House of Lords the bill was referred to a select committee, and afterwards withdrawn on the understanding that further experiments should be carried out during the recess. These experiments were made on the London and North-Western, the South-Western, the South-Eastern, and the Midland Railways. The author's electrical system was fitted on the London and North-Western Railway to a train running daily between London and Wolverhampton. Mr. Preece's system was fitted to trains on the South-Western and Midland Railways, and Mr. Walker's system was fitted to trains on the South-

Eastern Railway. In these experiments, the better to test the communication, it was arranged that the trains should be started from the stations by the guard from the rear van by means of the electrical communication, and that the behaviour of the apparatus should be reported by the guards in their daily journals. In this way the electrical communication was tested from every station at which the train stopped.

A very complete and exhaustive report of these experiments was made by Colonel Yolland to the Board of Trade on February 21st, 1868, in which, after giving in detail the arrangement of the experiments, the conditions under which they were carried out, and commenting upon the results obtained on each of the three railways, he expressed his approval of electrical communication, summing up his remarks in these words: "I have already expressed my opinion, founded on actual experience gained, that it—meaning communication by means of electricity—is quite practicable." Colonel Yolland's report was followed by the passing of the "Railway Regulation Act," which contained a clause rendering it compulsory on the part of railway companies to provide and maintain in good working order in every train running more than twenty miles without stopping, an efficient means of communication between the passengers and the servants of the company in charge of the train.

In November, 1868, a meeting was arranged extending over two days to make final experiments, and took place at York on the 27th and 28th of the same month. Amongst the systems which competed on that occasion were Harrison's cord system and the three electrical systems before referred to. Mr. Walker's electrical system was represented by a fitted train sent down by the South-Eastern Railway. Mr. Preece's by two vehicles—a brake van and a passenger carriage—furnished by the South-Western Railway Company; and the author's system by the London and Wolverhampton fitted train, sent down by the London and North-Western Railway Company. Two conditions (among others) had been laid down as essential in any system of communication to be adopted: (1) That the apparatus should be easy of access in case of need; (2) That it should be detective, to prevent the repudiation of the signal if sent without sufficient cause.

The results obtained at this two days' trial, briefly stated, were as follows: Mr. Walker's electrical system failed at the first day's trial, and another trial was made the day after, which was more successful. Harrison's cord system failed so far as the detective portion of the apparatus was concerned, and could scarcely be considered to fulfil the condition of being easy of ess, as it necessitated the opening of a window to get at the

cord. In other respects this system acted, signals being sent from one end of the train to the other, and from the passenger compartments to the front and rear of the train. The author's system proved successful in all respects; the apparatus was easy of access, was detective, and all the signals sent were received and acknowledged. Mr. Preece's system was also successful, but as it was represented by only two vehicles it could scarcely be considered to have been adequately tested at these trials. A mechanical system, however, appealed more to railway traditions than an electrical one, and at a subsequent meeting of the committee of railway managers it was decided to recommend the adoption of the cord system, the difficulty as to the detective portion being overcome by abandoning it altogether. Accordingly, a deputation of railway managers waited on the President of the Board of Trade, and his provisional consent was obtained for the use of the cord—"The Board of Trade reserving to themselves the power of reconsidering the question in the event of the system proving defective when tried on an extensive scale."

The South-Eastern Railway had already anticipated the Act of Parliament by the adoption of Mr. Walker's electrical system, and the approval of the Board of Trade was obtained for its continued use on that railway. The new cord system has now been tried for nearly four years and has not proved successful. Its failure as a means of communication when resorted to on several occasions led to an official investigation in 1871, and on July 15th, 1872, to the withdrawal by the Board of Trade of their sanction of this system of communication. The difficulties which interfere with the efficiency of mechanical systems arise from the varying width, and the very composite character of the rolling stock of this country, causing considerable friction to the motion of the cord. The passage of the train from straight to curved portions of the line and *vice versâ*, either slackens or tightens the cord, and tends to cause it to slip off the pulleys; the pulleys also become fixed and useless, as pulleys, from the action of weather and dust.

The author will now describe the three electrical systems before referred to, which have been tried by the only test of real value, that of being fitted to daily running trains. He will then explain the reasons which have led him to the construction of his special form of apparatus. Before, however, doing so, he wishes to submit the following conditions, which he considers an electrical system of communication may be fairly called upon to fulfil:

1. The cost of the apparatus in the first instance and its maintenance afterwards should not be expensive.

2. All parts of the apparatus should be constructed to stand rough usage, and in the event of the carriages being forcibly separated, the electrical couplings should release themselves without suffering any damage.

3. The couplings and other portions of the system of communication should be capable of being easily tested, and any fault occurring localized by a railway porter, or anyone, whether he possesses electrical knowledge or not.

4. The apparatus should be easy of access for the purpose of repair when necessary.

5. The failure of one or more couplings in a train should not interfere with the efficiency of the communication.

6. Should the fitted vehicle which has been standing for some time in an exposed situation be marshalled, and the electrical connections coupled without previous cleaning, the electrical continuity should be found to be perfect.

In the present advanced state of electrical knowledge, the successful application of electricity to signalling in trains is more a mechanical than an electrical problem. What the electrician chiefly requires is a circuit of metallic continuity. The securing this continuity in a train in motion, exposed as it necessarily is to dust, rough treatment, the action of the weather, &c., and liable also to be separated into various portions on the road, or to have fresh vehicles added to it, depends chiefly on the mechanical construction of the various parts, and a recognition of what each part is required to perform. In explaining electrical systems of other inventors, the author feels the difficulty of being himself personally interested; he therefore proposes in any remarks he may feel called upon to make on inventions other than his own, to confine himself as much as possible to the broad principles of construction on which all practical men are more or less able to form an opinion.

Mr. Preece's, Mr. Walker's, and the author's systems are so far alike that one-half of the electric circuit consists of an insulated wire running along or underneath the carriages, and the other half of the circuit of the railway metals and the wheels of the carriages. Mr. Preece employs for his coupling a solid brass hook, over which a galvanized iron eye passes, a flat spring pressing upon the eye to ensure better contact. This eye is attached to a hempen rope, having two conducting wires wrapped spirally on the rope; over this is woven a hempen serving, giving the conducting rope the appearance of a thick sash-line. The carriages are fitted at each end with a brass hook and a conducting rope, so placed that whichever way the carriages travel the eyes and the hooks of the couplings are opposite one another. The alarums consist of ordinary trem-

bling bells, with an arrangement to prevent the bells being rung by oscillation.

The passenger signalling apparatus which was first adopted consisted of a circular box in each compartment, having a glass face, which the passenger had to break. The effect of this was to liberate a sort of Jack-in-the-box arrangement, which caused semaphore arms on both sides of the carriage to fall, and in doing so to complete the electrical circuit and to set the alarums in the vans and on the engine ringing. The Jack-in-the-box arrangement, and also the outside signals, were subsequently abandoned, and the circuit completed by the passenger moving a commutator handle over a certain fixed distance. In the trains first fitted by Mr. Preece a releasing coupling hook, similar to one which had been adopted in France, was used. This coupling, was, however, expensive and costly to maintain, and was afterwards abandoned for the solid hook, which is cheaper. The solid hook, however, possesses the disadvantage that if the carriages be separated from one another without previously undoing the electrical couplings, the ropes are liable to be broken.

Mr. Walker adopts for his coupling a hard spiral brass wire enclosed in a vulcanized indiarubber tube. The spiral wire is terminated at each end with brass rings, which pass over fixed brass hooks attached to the centre of the carriages near the roof. The passenger signalling apparatus consists of a circular wooden box placed in each compartment, and having a handle in the centre, which, when pulled out, liberates an outside signal, and closes the electric circuit through the electric bells in the vans. The van apparatus consists of a rather elaborate switch, having six different positions, and a Leclanché battery and an alarum. The apparatus on the engine consists of a small electrical semaphore and an electrical bell. The couplings adopted by Mr. Walker would appear to answer on the South-Eastern Railway, but the author does not consider they would be suitable for adoption on railway lines generally, the electrical continuity depending upon a very large number of metallic surfaces being in clean contact with one another.

The single coupling adopted by Mr. Walker involves four metallic surfaces being kept clean to ensure electrical continuity between one pair of carriages. In the case of twelve vehicles the electrical continuity depends upon 44 surfaces, in 24 carriages, upon 82 surfaces, and so on, the failure of metallic contact at any one of these surfaces interrupting the communication between the rear and the front of the train. The couplings are liable to be destroyed by the separation of the carriages if the couplings be not removed before breaking

up a train. The amount of extension which the couplings permit is also limited; this involves keeping in stock couplings of various lengths to meet the case of carriage trucks, &c., being introduced into a train. The switch used in the vans has to be adjusted to various positions, in accordance with printed instructions placed in the vans, and this throws upon the guards an amount of care and attention which it would be desirable to avoid; it also leads to complication, and consequently to greater liability of the communication being put out of order.

That Mr. Walker's system has worked well the author attributes to the very elaborate and complete organization of the electrical department of the South-Eastern Railway Company. The amount of care and attention which the electric communication receives on that railway can be best judged by the perusal of a paper, written by Mr. Walker, describing the working of his system, which has been printed as an appendix to an official report, drawn up by Captain Tyler, and published in 1872. From this paper it would appear that at the date of February 24th, 1872, the South-Eastern Railway had twenty-four fitted trains. The following quotation has been taken from under the heading of maintenance:

"(53) The annual expenditure for the maintenance of the 616 vehicles, with all their necessary apparatus, is 274*l.*, or at the average rate per vehicle of 8*s.* 10*d.* (eight shillings and tenpence).

"(54) The trains are marshalled or made up, for the most part, at the Bricklayers' Arms Station, in the Kent Road. Our inspector of train intercommunication is stationed there. His duties are to inspect the rolling stock of up-trains that have come in, or down-trains that are going out; to collect into his stores 'guards' sets' and 'semaphore bells' from vans or engines that are about to remain in the sheds for a time; to overhaul vehicles and apparatus, and rectify anything that is wrong. Many of the trains he sees coupled up at Bricklayers' Arms. Some trains he attends to Charing Cross and Cannon Street, and sees them started in order. He sends in a daily report to me, in which he gives his time-table, with his whereabouts throughout the day, showing what time he is at the carriage depôt, and what trains he attends at the Charing Cross terminus. He also gives the number of couplings used on each train, and the registered number of the guards' sets in each van; and he gives a note of each train right or wrong. Enclosure No. 11 is a copy of his report* for a Sunday in the

* See Captain Tyler's "Report on Accidents which have occurred on Railways during 1871," published in August, 1872.

winter, 1872, January 21; and No. 12 of a Saturday in the summer, 1871, July 15.

"(55) At Charing Cross Station, where the down-journey of trains begins and the up-journey ends, a porter is told off to put the electric couplings on a down-train, and to collect them into a store provided on the arrival of an up-train.

"(56) At Cannon Street, where the City portion of a down-train joins the Charing Cross portion, a porter couples up the two parts.

"(57) The telegraph clerks at Dover and Folkestone test the vehicles and apparatus that have arrived in down-trains before they are started in up-trains, and send in a weekly return of the daily examinations made. Enclosure No. 14 is a copy of the Dover report for 1871, October 7. It gives the date, the name of the train, the registered numbers of the 'guards' sets,' the numbers of the guards' vans, the numbers and description of the carriages, and the trains when tested complete. A telegram to the inspector at Bricklayers' Arms advises him of anything requiring his attention.

"(58) At Margate, Ramsgate, Deal, Tunbridge Wells, and Hastings the station staff receive the trains on their arrival, and marshal and couple them up before starting.

"(59) At Ashford a telegraph lineman, or one of the clerks, sees that the branch portion of the train is properly coupled to the through portion.

"(60) The company's carriage shops are at Ashford. The district telegraph inspector is at that station. Notice is given to him of any fitted stock that has been in for ordinary repairs and is coming out again. He or his lineman examines the vehicles and rectifies anything that has been disturbed by the carriage fitters.

"(61) At Tunbridge a couple of men from the telegraph workshops there meet every fitted train that stops at the platform, and test the train from end to end, to note how it is working.

"(62) A travelling sub-inspector is employed in looking up couplings and 'guards' sets,' and doing ordinary repairs to rolling stock, &c., whenever required."

A further quotation taken from the same report, under the heading, "Instructions to Guards and Others," would seem to indicate that the South-Eastern Railway Company have found it necessary to issue very stringent regulations to ensure careful management on the part of the servants of the company. For instance:

"(4) Shunters or porters who couple and uncouple the carriages must also couple and uncouple the electric couplings, and

will be held responsible for any damage that may occur through neglect of this order.

"(5) Careful attention is to be given to the unhooking of the electric couplings when carriages are detached from trains in speed.

"(19) Several cases have occurred where the telegraph apparatus has been wilfully damaged, bells broken, &c., and particularly couplings lost or mislaid; and in a recent instance the guttapercha covering of wires has been cut about by some mischievous person. Damage of this sort can only be caused by the company's servants, who are hereby warned that such cases will be strictly inquired into, and the offending party severely dealt with.

(By order) "C. W. EBORALL, General Manager."

A system of communication requiring so much supervision as is bestowed upon it on the South-Eastern Railway—a line where the distances travelled are comparatively short, where there is not much breaking up of trains or interchange of rolling stock with other companies—can scarcely be considered to be suitable for the great trunk lines of the country, where interchange of rolling stock is the rule, the distances travelled are great, and where close supervision would be very difficult to maintain.

Since the author first directed his attention to electric train intercommunication—now seven years—he has tried a great variety of couplings and many forms of apparatus. He has arrived at his present construction from experience gained during seven years of the behaviour of his apparatus subjected to the vicissitudes incidental to railway traffic. His system has been fitted to two trains—the royal train of the London and North-Western Railway, and to the London and Wolverhampton train of the same company. The electric communication on the royal train is only used when Her Majesty travels. The train has usually consisted on these occasions of seven or eight saloon carriages (including Her Majesty's saloons), four first-class carriages, one truck, and two break vans. After a royal journey the train has usually been broken up, and the fitted first-class carriages and brake vans drafted into the regular traffic; the saloon carriages also have been used as occasion may have required.

It may be [illegible] that as the electric communication on this train has o[illegible] used on special occasions, when more than ordinary [illegible]ken, no fair criterion of the system as a system [illegible]ed from it; but as a matter of fact to the invento[illegible]een anxious to discover the weak portions

of his system with a view to their elimination, this train has afforded the most valuable experience. It is well known that even railway metals when unused wear out faster than metals over which there is a moderate traffic, and that machinery keeps in better order when in use than when left idle and not looked after; and so it is with the electrical connections of the carriages composing this fitted train. The carriages are used for the purpose of traffic, but the parts belonging to the electrical system are out of use, and may be said to be entirely neglected during the greater part of the year. The electrical couplings and the other parts of the system can scarcely be more severely tested than they are under such circumstances, and when the time comes for collecting the fitted vehicles from various parts of the country for another journey, an examination of the electrical couplings and apparatus is very suggestive as to what is required for the successful application of electricity to train intercommunication.

On the London and Wolverhampton train, the author's system was tried under conditions of fair ordinary traffic. This fitted train commenced running in January, 1868, and continued to run nearly two years, when the carriages were called in for repairs, and the train replaced by another having the cord. This fitted train left Euston for the down journey at 6 P.M. daily (Sundays excepted), arriving at Wolverhampton some time after nine o'clock at night, leaving Wolverhampton for the up-journey a little after 7 A.M. on the following morning, and arriving at Euston at 10.30, the distance travelled in the twenty-four hours being 250 miles. During the time elapsing between the arrival of the train at Wolverhampton on Saturday night and its leaving Wolverhampton for the up-journey on Monday, the train stood in a siding outside the station. The number of guards who worked this train were twelve altogether, six guards from Wolverhampton working the up-journeys, and six guards from London working the train on the down-journeys. To meet the case of unfitted carriages being inserted in the train, three or four pairs of long coupling ropes were carried in the vans to connect across the unfitted vehicles. The guards' reports showing the working of the system being the private property of the London and North-Western Railway Company, the author is not able to refer to them; but in a printed letter addressed to the general manager of that railway by Mr. Martin, bearing date Sept. 7th, 1868, eight months after the system had been in use, the following passage occurs:

"The performance of the apparatus has been marked by the most unvarying regularity, as the guards' daily journals will testify, whilst the cost of maintenance is merely nominal. When

the electric communication was fitted to the London and Wolverhampton train, a mechanic accompanied it during the first fortnight, for the purpose of instructing the guards. After that the only supervision it received was from an unskilled labourer, who attended at the Euston Station, wiped the couplings with a piece of cotton waste after the carriages had been washed, and saw that the electrical connections were coupled up before the train left the station; there was no one appointed at Wolverhampton to look after the electrical connections. The train was started from the stations by means of the electrical apparatus, and its behaviour was daily entered by the guards in their reports. The number of stoppages made in the up and down journey was twenty-two, and consequently the communication was tested twenty-two times daily."

The author will now proceed to describe the construction of the different portions of his electrical system, examples of which are before the meeting; he would also call attention to a coupling which was removed from a carriage after having been fixed for two years. The coupling ropes are made by wrapping a wire spirally round a hempen cord; seven of these cords are then laid longitudinally and bound together by two or more servings of hemp, which have been soaked in an insulating protecting compound. A very flexible conducting rope having seven separate conductors is thus constructed, and in practice this construction is found to be very durable, for there are seven conductors which touch one another throughout, and should one or more of these be damaged the continuity is still maintained, and however much the rope may be damaged the electric continuity is complete. Malleable cast-iron eyes are attached to the ends of the connecting ropes where the couplings are made, and these pass over and are firmly grasped by strong malleable iron hooks actuated by powerful springs placed in cast-iron boxes attached to the carriages. The eyes of the coupling ropes at the point of contact are coated with copper, and the coupling hooks have a plate of brass attached, against which the hooks press; this ensures more perfect contact as the iron is liable to oxydation when exposed. The advantages the author claims for this coupling are, that the act of coupling cleans the metallic surfaces. The coupling is strong, and releases itself without damage if the carriages be separated from one another. It is also constructed of cheap materials, every part of which can easily be renewed at a small cost.

The a[illegible]s in the vans consists of a battery placed in a box, a[illegible] electric alarum, and the connections are made by s[illegible]ng them up on brass hooks. The apparatus on th[illegible]sists of an electric alarum and a visual signal

combined. The passenger signalling apparatus is a small metal box, having a white screen in front on which are printed the necessary instructions for the guidance of passengers. To gain the attention of the servants of the company a small handle underneath the box is pulled downwards; this discharges an electric lock, closing the circuit, and at the same time exhibiting a red signal on the face of the carriage apparatus. The passenger, after having closed the circuit, can move the handle freely up or down, but cannot discharge the lock. This is done by a special key in the possession of the guard. The author now proceeds to the question of cost. It is obviously unfair to compare an electrical system which is cheaply maintained, which places the means of communication within easy reach of the passengers, and which is provided with a detective arrangement to prevent the repudiation of a signal when one has been sent, with a crude mechanical system of expensive maintenance, which experience has shown cannot be depended upon, which is not provided with a detective arrangement, and which necessitates opening the window and then finding the cord, to say nothing of the passenger being liable to open the window and pull the cord on the wrong side. The estimated cost of fitting up the London and North-Western Railway Company's rolling stock with the electrical system, including the apparatus for the vans, engines, &c., was in 1868, 3*l.* 12*s.* per vehicle. The total cost of fitting up the whole of the rolling stock of that railway was estimated at that time to amount to 8301*l.* 11*s.* The cost of fitting the cord to the London and North-Western Railway stock, from an official report of Captain Tyler's of August 9th, 1871, would appear to have been 6238*l.* 7*s.* 6*d.* Although the first cost of an electrical system is somewhat greater than that of the cord, in the very important question of maintenance, the electrical will compare very favourably with a mechanical system, as there is scarcely any wear and tear, and little else is required than supplying from time to time a few inexpensive chemicals to the batteries.

In the engravings Fig. 1 shows the spring hook and eye, releasing, coupling, and flexible conducting rope, containing seven conductors, which is used for connecting vehicle with vehicle. Fig. 2 shows a complete set of apparatus for a guard's van, consisting of an electric alarum, a galvanic battery, and a signalling key. A is the alarum, which is portable, and electrically connected by being simply hung on two brass studs. B is a galvanic battery, also portable, and connected up in the same way as the alarum, by being hung upon metal studs. C is the signalling key by which the guards can send either continuous or intermittent signals. Fig. 3 shows the passenger

signalling apparatus which is fitted in the carriages. Fig. 4 shows the same apparatus after the communication has been made use of by a passenger, the compartment from which the signal has been sent being indicated by a red screen appearing in the opening on the face of the signalling apparatus. Fig. 5 shows the internal construction of the alarum used in the vans. Fig. 6 shows the combined visual and sound signal used on the engine. S is a red screen attached to the striking lever, carrying a hammer which strikes the bell. When the communication is made use of the red signal oscillates behind an opening and catches the eye of the driver, the hammer striking the bell at each oscillation. At night a lamp is placed behind the alarum and the visual signal is an intermittent red light.

Before concluding, the author will offer a few observations on outside signals in connection with systems of communication. In Mr. Preece's system they were adopted in the first instance and subsequently abandoned. On the South-Eastern Railway they are still used. The author has never adopted them; he considers them unnecessary and objectionable, inasmuch as they increase the cost of maintenance; for unless constant attention be bestowed they are liable to become fixed by the action of weather in the same way as, experience shows, frequently occurs with the pulleys used in connection with the cord. The first and chief use of a system of communication will be to gain the attention of the servants of the company in the event of an accident occurring to the train, such as a carriage being on fire or an axle breaking. The second use will be for cases such as sudden illness, &c. The third use will be to call attention in the case of outrage, and experience has shown that cases of this kind are of very rare occurrence. Whenever the communication is made use of from the causes just mentioned, there will be no difficulty for the guard to discover the compartment from whence the signal has been sent. The only times when there is likely to be any difficulty will be when a signal has been sent without sufficient cause, and whenever this occurs the guard will be able to discover the compartment from the signalling apparatus which has been used.

There is another point on which the author would remark, *viz.* the use of double *versus* single couplings between the vehicles. An engineer would certainly never trust a continuous brake if the construction were such that the failure of one of the blocks to act impaired the action of all the blocks throughout the train. Yet the use of a single coupling in an electrical system of communication is almost a parallel case. In a double coupling the ropes at one end are in perfect continuity with the insulated wire running throughout the train, and instead

of the electric continuity depending upon a large number of metallic surfaces being in clean contact with one another, the failure of any one of which divides the communication, interruption to the continuity can only occur in the unlikely event of there being two defective couplings between a pair of carriages. There are many points in connection with train intercommunication which the author would like to have enlarged upon if time had permitted. The author, however, has done his best to bring before the Society what he considers the main points of the subject. He has also endeavoured to lay before the Society the principles which have guided him in the design of a system which he has built up step by step. The railway companies of this country will soon have to decide upon some system of communication, and the author trusts that before that decision be come to, his system, as well as others, may be fairly tested and decided upon its merits.

DISCUSSION.

Mr. S. J. Mackie said that it was most important that public attention should be forcibly drawn to the necessity of some proper means of intercommunication between the passengers and the guards in railway trains. He had known from personal experience how very inefficient the rope system was. Its inefficiency had been shown in two recent cases. One case was that of the Rev. Mr. Moore, who was attacked by a maniac; and the other was that of a little Norwegian girl who fell out of the railway carriage. In the first case not one of the passengers knew where to find the rope, and he (Mr. Mackie) very much questioned whether they would have been able to give a signal if the rope had been found; for the Board of Trade Inspector, Captain Tyler, had recorded in one of his reports that he had pulled in more than 18 feet of rope without effecting a signal. The rope system was adopted because the railway companies thought that it would be very dangerous to give passengers the power of stopping trains. He believed that even with an efficient system cases of needless stoppage would be very rare. No rope apparatus would ever answer the purpose. There had been an attempt made recently to combine the American rope system with the Patteson rope system, and the result had been an utter failure. There were other mechanical systems, and the pneumatic system, which had been tried and found to have some good qualities; but his belief was that no mechanical system could succeed, and that an electrical system of some kind must ultimately be adopted. The comparative values of the different electrical systems deserved anxious and careful

consideration. There were many points of merit about the system which had been described. The author of the paper had alluded to certain inventions which had been made some time since; but besides those there were other inventions which had been kept back from the public because of the position which the Board of Trade took in deciding to have the Harrison rope system. At the present moment the railway companies were actually running with a condemned system under the sanction of the Board of Trade.

Mr. P. F. NURSEY said that he was present a short time since at the official trials of Colonel Binney's electrical system of train communication, the results of which were very successful. The system had been worked for two months previously on a Great Eastern Railway train running between Stratford Bridge and Victoria Park. The signalling apparatus consisted of a communicator, which had a projecting stud or "push," and also an indicator; a communicator was placed in each compartment of the carriage. In each guard's van was a battery and an ordinary electric bell, connected with the "push" by two wires carried along the roofs of the carriages to which they were fixed. Those conductors were coupled between the carriages by means of a hook-and-eye arrangement, a spring pressing the coupled parts together, which ensured perfect contact and complete metallic communication throughout the whole length of the train. One terminal of each bell in the guards' vans was connected to one pole of each battery, the other terminal being connected to one of the conducting wires. The other conducting wire was connected to the second pole of the battery, so that until the two conductors were connected together no current of electricity could pass. The connection was made by the passenger pressing the "push" on the signal apparatus, which caused the bells to ring in the guards' vans. By the same act of the person signalling a couple of discs at the ends of short levers were mechanically released, and falling outwards from either side of the carriage in which the signal was made, indicated to the guard the part of the train requiring his attention. The disks were afterwards restored to their original position by the guard. The compartment from which the signal issued was easily determined by inspecting the communicator, in which was a small circular opening through which an indicator was visible when the signal had been made, and which could only be restored to its normal position by the guard with a special key. The signal bells in the guards' vans continued ringing until the indicator had been thus restored. If in making up a train it became necessary to include a carriage not fitted with the apparatus, the continuity of the conductors was preserved by

g. 3.

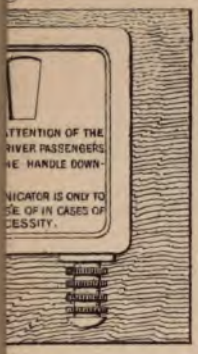


Fig. 4.

Fig. 5.

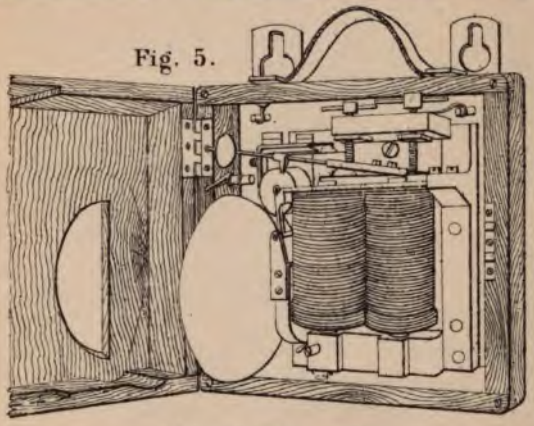
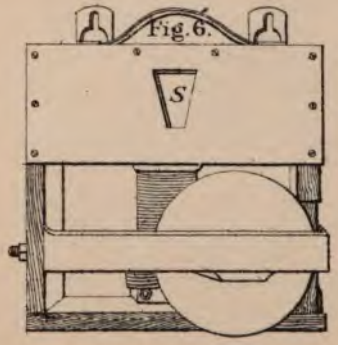
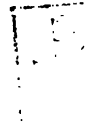


Fig. 6.



B. Alexander Lith.



the use of spare lengths which were readily attached to the carriage by means of a screw clip at each end, the coupling being effected as in the other parts of the train. For signalling at night coloured lamps with shutters were used in place of the discs. The removal of the shutters was effected by the falling of the disc signals, which touched a spring attached to each shutter, which was by that means released and the light exposed to view. For communicating between the guards and the engine driver, an electric bell was fitted on the engine, and connected with the battery in the guard's van. Contact was made or broken by means of a lever spring, and with that arrangement the bell on the engine was prevented from ringing when the signalling was going on between the passengers and guards. When one guard desired to communicate with the other, he merely pressed the stud upon the front of his bell-case, no levers nor armatures being used in Colonel Binney's system. Should the train become separated while running, the coupling would of course be broken, but before breaking would be pulled taut. By that act the ends of the coupling would be brought into metallic contact with the cases which protected the joints, and which would cause the guards' bells to ring, thus giving them notice of an accident. The official trials were made by Captain Tyler, R.E., on behalf of the Board of Trade, and the results were perfectly successful.

Mr. A. Williams asked Mr. Varley what system was used on the London, Chatham, and Dover Railway. There was a rope running through a ring on the floor of the carriage, but he did not know whether the rope had ever been practically used.

Mr. V. Pendred inquired how long Mr. Varley's batteries would last, and what was the cost of their maintenance; also whether the lines could be depended on in all states of the weather, and whether a mass of ice frozen over the whole coupling would affect the insulation.

Mr. Druitt Halpin said that he was recently travelling by rail between Ostend and Berlin, and in the train the whole apparatus, consisting of batteries, wires, bells, and signals, was contained in one carriage, and yet it would not act. That seemed to show that electrical systems required great care. Mechanical engineers would perhaps be more forcibly appealed to by a mechanical system. He had recently examined a system of that kind, in which a shaft went through the roof, just clear of the hoop-sticks, and on that shaft was a wheel with teeth gearing into a chain which geared into another wheel farther down at a convenient height for passengers to reach. On that was a crank handle which was turned. That carried an arm with a hammer at the end which struck a bell. The ends of

the separate shaft contained in each carriage were coupled up outside. One end of the shaft had a small T-piece, and the other end had a bar with eight or ten projecting arms. The arms projected about 2 feet from the carriages. The arrangement might prove particularly damaging to passengers in the end compartment of the adjoining carriage to the one carrying the armed portion of the coupling in the event of a collision.

The PRESIDENT said that with Mr. Varley's apparatus it would seem to be a difficult matter for a guard to find out who had given the signal in the event of a train being stopped by a passenger. If the train consisted of twenty-five or thirty carriages, with four or five compartments in each carriage, great delay might occur before the right compartment was found. That would not be the case if the signal was an external one. Perhaps Mr. Varley could give a reason why an external signal should not be used.

Mr. VARLEY, in replying to the discussion, said he was present at the official inspection of Colonel Binney's system, which as there exhibited was a very crude contrivance; the couplings were not strong enough, and they would be liable to be damaged by the porters when washing the carriages. The batteries also were not adapted for the purpose of train signalling; and the fittings generally appeared to him not calculated to resist rough usage.

In reply to a question which had been asked, he (Mr. Varley) employed the railway metals and also the coupling rods of the carriages for the return circuit, but he relied chiefly on the coupling rods, and was independent of the permanent way. He used a single insulated wire underneath the carriages, with branch connections which were soldered to the coupling hooks and coupling ropes. There were two coupling ropes and two coupling hooks attached to each vehicle, so there was a double connection between the carriages, but only a single insulated wire underneath the vehicles. The reason for employing double couplings was explained in the paper: a single one would answer the purpose, but could not be relied upon, as the failure of any one coupling would then divide the circuit. The double couplings also rendered the detection of any want of continuity in the couplings a simple mechanical operation, which could be performed by anyone not having a special training. The couplings would release themselves without being damaged if the carriages were forcibly separated.

This system of c nication could be made to indicate the breaking away of a train. The inspecting officers of the Board of Trade a great deal of importance to a break-away signal fo of any system of train intercommu-

nication, and in nearly all the electrical systems which had been brought forward some arrangement had been proposed with that object, but the Act of Parliament did not insist upon a breakaway signal. It was not so simple a thing as it appeared at first sight, to construct an efficient breakaway signal. In all those which had come under his (Mr. Varley's) notice the circuit was closed either by a spring or a lever actuated by a spring coming in contact with a metal surface. Breakaway signals so constructed could not be depended upon. In his earlier experiments he had constructed a breakaway in which the circuit was closed by a strong spring coming into contact with a metal knob, but he found it could not be relied upon. It acted very well when the surfaces were clean, but the surfaces never remained clean for any length of time; they became coated with dust and dirt after a very short run, and then they would not make electrical contact. After several trials, however, he had succeeded in constructing an efficient breakaway coupling, examples of which were before the meeting. With those couplings the effect of the train breaking into two parts was to cause in each section a lever actuated by a powerful spring to come into contact with an inclined plane, the surface of which it scraped, clearing away the dirt and making electrical contact. The couplings after the levers had been discharged released themselves without being damaged in any way.

In reply to the questions asked by the President, the pull in the passenger compartments could be readily grasped by the thumb and finger. It had been made purposely somewhat small and of such a shape that it must be pulled intentionally. The shape of the handle and its size was, however, a matter of detail, as was also the position in which the passenger signal was placed. He preferred the centre of the compartment, considering that position the most generally accessible, but it could be placed outside the carriage if desired, or it could be let into the framework of the carriage, so as to show the tell-tale signal on the outside.

Two cases had occurred of passengers pulling the passenger signal on the London and Wolverhampton train from curiosity: a description of what then happened he thought would be the best answer which could be given to the question he had been asked, as to how the guard would discover the compartment which had sent the signal. Both those cases occurred shortly after the fitted train began to run, and in both cases the train was stopped. The effect of the stoppage was to cause the passengers to put their heads out of the windows to learn the cause of the train being pulled up, with the exception of the compart-

ment from whence the signal had been sent; the guard therefore had no difficulty in finding out the compartment, and the tell-tale signal completed the detection.

The reasons why he did not recommend an outside tell-tale signal he had stated in the paper. It could of course be provided, but it would considerably increase the cost of maintenance, and he thought the simpler the system and the fewer the parts the better. He would remark that during the whole time the fitted train was running only two cases occurred of the passenger signal being used without sufficient cause, and both of those took place within a month after the apparatus was fitted. That showed there was no fear of the apparatus being resorted to unnecessarily.

In reply to the question of supervision he had stated in the paper that the only supervision his system received when fitted to the Wolverhampton train was from an unskilled labourer who attended at Euston a little before the train started; saw the system was coupled up before leaving, and also tested the apparatus, which was a work of only a few minutes.

The cost of chemicals was 3*d.* per battery. The solution used was sal ammoniac dissolved in water, a solution of common salt, or a mixture of it with sal ammoniac might be substituted, and then the cost would be somewhat less. The duration of the battery depended upon the amount of work it was called upon to perform, but the batteries would keep in good order for a great many months without having to be recharged.

The battery employed was that of Leclanché, but fitted up and modified by himself (Mr. Varley) to adapt it for railway use. The Leclanché battery fulfilled admirably the conditions required for electric train intercommunication; there was no waste of chemicals when the battery was not being used; that was not the case with any other form of galvanic battery. The Leclanché battery also had the property of developing a large amount of electric force when first brought into action, but if the circuit remained closed for any length of time the tension rapidly fell and the electricity developed became very much reduced; but as the battery very quickly recouped itself when allowed to rest for a short time, that which was a great defect for many purposes was really an advantage when the battery was applied to the purpose of train intercommunication, for the consumption of chemicals was lessened proportionately to the decrease in the development of electricity, and consequently if the circuit w losed for any length of time the waste was very much n it otherwise would be. At the same time the pment of force lasted long enough for signallin

Snow or ice accumulating on the couplings would not interfere with the working of the electric communication, there would be a little leakage when the snow began to thaw and whenever the carriages were wet, but the leakage with the low tension of the electric current employed was so small that it would be of no practical moment.

A low temperature would not interfere with the action of the batteries, unless the temperature was so cold as to freeze a solution of sal ammoniac. He thought there was little fear of the batteries being subjected to so low a temperature in England, but if there were any danger the batteries might be placed in cupboards, with a lighted lamp inside.

It was the cord communication which was used on the London, Chatham, and Dover Railway, and he had been informed that it cost 30*s.* per carriage. The cost of the electrical couplings and running the insulated wire underneath would not be more than 20*s.* per vehicle.

In reply to the questions respecting the construction of the apparatus, Mr. Varley said that the alarums were constructed on a solid frame of cast iron, so that there were no parts liable to be shaken loose. The passenger signal was made entirely of metal, and so designed that the external parts could be readily got at without disconnecting the apparatus. When the passenger signal was put into action the circuit was closed in a similar manner to the breakaway signal already described. The coupling ropes and hooks were strong and durable, and capable of resisting very rough usage, and every part of the system admitted of easy renewal or repair. In the construction of this system of train intercommunication he (Mr. Varley) had endeavoured to obtain in the apparatus composing it, efficiency, durability, and cheapness of maintenance.

October 6th, 1873.

WILLIAM MACGEORGE, VICE-PRESIDENT, IN THE CHAIR.

RECENT IMPROVEMENTS IN PUMPING ENGINES FOR MINES.

By HENRY DAVEY.

The relative merits of different types of pumping engines having been discussed on former occasions by the members of this Society, it is not with a view of renewing the controversy that the author selects this subject, but in order to bring before the Society two recent modifications in pumping machinery. In doing so he proposes to touch upon some important points connected with pumping engines generally.

In designing pumping machinery for mines, as also in designing steam machinery of all kinds, the three great questions which should be thoroughly and relatively considered are—economy of fuel, economy of maintenance, and economy of construction. The importance of economy in fuel was never more keenly realized than at the present time, notwithstanding the great advances which have been made to reduce the consumption. Our steam engines consume annually 37,000,000 tons of coal, which at the present moment may, perhaps, be reckoned at 15*s.* per ton, representing over 27,000,000*l.* sterling; an economy of 25 per cent. would therefore effect a saving of nearly 7,000,000*l.* annually. In Cornwall the cost of coal has, ever since the introduction of the steam engine into that county, been a subject of vital interest to the mining community, and in a period of twenty years the improvement effected in the Cornish pumping engine reduced the consumption of coal to one-third that at first required, making a saving of 90,000*l.* per annum, which, at the present price of coal, would amount to 140,000*l.* sterling. Whilst the engineers of Cornwall were thus perfecting their engines and developing the principle of expansion, colliery proprietors could well afford to be careless on the matter, but the time has now arrived when coal which can be used for steaming purposes in collieries meets with a profitable sale for other uses. Besides this, our coal mines are being worked deeper and deeper every year, so that the proportionate

amount of pumping necessary for a given "output" is greatly augmented. At a coal pit in the North of England where the author is now putting down plant, the weight of water pumped to the surface in draining the workings will be nearly four times as great as that of the coal raised. With such enormous proportionate amount of pumping it is not unusual to find a consumption of from 12 lbs. to 16 lbs. of coal per horse-power per hour. A good compound engine will work with less than one-fourth that amount of fuel. The saving therefore to be effected on 400 horse-power of actual work by the substitution of a compound engine would be at the lowest estimate 36 tons in twenty-four hours, which, taken at 5*s.* per ton at the pit's mouth, would amount to the modest sum of 2700*l.* per annum. The old 400 horse-power engine, consuming about 50 tons of coal per day, would weigh probably from 90 tons to 100 tons if a single-acting engine, as many are, whereas a compound engine of the same power, which the author will presently describe, weighs only about 55 tons. The author is now constructing one of these engines to replace an old one, engaging that it shall consume only one-fourth the fuel now used.

It is well known that the leading principle of economy in the steam engine is that of expansion of steam, and the introduction of the second cylinder to form a compound engine gives no theoretical advantage, but is purely a practical question. By the introduction of the second cylinder the maximum strain thrown on the piston and its attachments is greatly reduced, and a greater uniformity of motion and of strain is secured. In the example before us the variation of force during the stroke is about three to one with an eightfold expansion, whereas with a single-cylinder engine it would be as eight to one. In Cornwall some years ago, during the race for economy of fuel, engineers carried expansion in a single cylinder to the utmost limit; Taylor's 85-inch Cornish engine, having a 10-foot stroke, was worked at the United Mines with a tenfold expansion, and did a duty of 112 millions, but it ultimately broke down from the excessive strain thus thrown on the pump rods. Since then a lower and safer grade of expansion has been employed. This engine proved that which has been proved over and over again, namely, that such a grade of expansion cannot be safely employed in a single-cylinder engine. Cornish engines are now worked with a threefold, and at most a fivefold expansion, and this partly accounts for the falling off in the duty reports. Experience has proved that the second cylinder is necessary where expansion is carried to a great extent.

The author would here remark that the practice of recording the duty which has been carried out in Cornwall might be

advantageously adopted in the colliery districts, but the report should be more complete than those of Cornwall, and should give the grade of expansion and the boiler pressure employed, besides separating the duty of the boiler from that of the engine. Thirty years ago the average duty of pumping engines in Cornwall was 67,000,000, whereas now it scarcely reaches 48,000,000, and it is a great pity that the duty reports have not recorded the grades of expansions, for then we should probably be able readily to discover the cause of the falling off in efficiency.

There are two types of the differential expansion pumping engine—the single cylinder and the compound engine—the designs and arrangements of each being varied to suit different applications. The engravings, Figs. 1 to 6, illustrate in elevation, plan, and section a compound engine constructed by Messrs. Hathorn, Davis, and Campbell, for the New Hartley Colliery, in the North of England. It consists of a pair of horizontal cylinders placed end to end, the bottom of the high-pressure cylinder forming one of the covers of the low-pressure cylinder. There are two piston rods to the low-pressure piston which pass through tubes cast on the jacket of the high-pressure cylinder, so that they are in the same plane with the rod of the high-pressure piston. These three rods are coupled to one crosshead, to which is attached the connecting rod for working the pumps. The cylinders are firmly secured to a strong girder bed, and the condenser is carried on a separate bed at the rear of the engine, the air-pump bucket being worked by means of a tail rod from the low-pressure piston; such is the simple form of the engine, but the valve gear, though equally simple in construction, is more difficult to describe without the aid of the model which lies on the table.

The main slide valve is actuated by means of a lever, deriving its motion partly from the main, and partly from a subsidiary, piston. The connection to the main valve is in the centre of the lever, and the connection to the two pistons at the opposite ends. The action will be best understood by assuming the main piston to be at rest at one end of the cylinder; to start the engine, steam would be admitted to the subsidiary piston, causing it to carry the lever forward, opening the main valve, admitting steam and thereby causing the main piston to com-
' 'e its stroke; but this piston in doing so moves the main
· in the opposite direction, and cuts off steam. The main
) then has a differential motion, compounded of the
)ns of the main and subsidiary pistons. The motion given
ıe subsidiary piston is rendered constant by means of a
le · cataract, which the author will presently describe.
end of the lever has a constant motion, inde-

pendently of the engine itself, and the other end has a varying motion, depending on the varying motion of the main piston. The resultant motion of the main valve being obtained from the centre of the lever, and being compounded of a varying and a constant motion, must necessarily also vary; variations of load on the engine produce variations in the motion of the main piston; in other words, the increase or decrease of load increases or diminishes the supply of steam to the cylinder. The cataract end of the lever is attached to the subsidiary piston rod, which rod is continued into the cataract and is provided with a gun-metal piston, fitting the cataract cylinder; the cylinder is filled with water, and is provided with a passage leading from one end to the other; in the passage is fitted an adjustable plug for regulating the speed of the engine.

It should be understood that the force acting on the subsidiary piston is far greater than that required to move the slide valve, the surplus power being absorbed in driving the fluid in the cataract through a small opening. As the resistance of the fluid increases with the square of the speed, it requires a very great variation of force on the subsidiary piston to cause a very small variation in the speed, so that the speed is practically constant for a given adjustment of the cataract plug, although the boiler pressure may vary. It will therefore be seen that the chief peculiarity in the invention is the simple manner in which the engine is rendered safe in working against variable loads, automatically and instantly varying the distribution of steam with every minute increase or decrease of resistance. A slight pause is produced at the completion of each single stroke of the piston, during which time the pump valves fall to their seats, preventing slip and the shock which occurs when pump valves close under pressure from a moving plunger. The freedom from shocks in the pumps is an important point, as it affords security against accident, such as bursting pipes, &c., and the durability of the valves and seats is greatly increased. The action of the valve gear of the engine is so sensitive and so perfect, that the load may be greatly varied on the engine when it is in full work, without any injurious effect. Engines on this plan may be employed to pump direct into town mains without the intervention of stand pipes, balance valves, or anything of the sort. There is great economy in the construction of these engines and in the buildings which they occupy, as will be seen from the drawings and the following Tables of dimensions and powers, &c.

The columns headed "units of work" are for ready comparison with the work required to be done in any given example. Thus, let it be required to pump 250 gallons of water 200 feet

high per minute, then the number of units of work to be done = 250 × 10 × 200 = 500,000, and on reference to the Tables the size of the engine required for the work is readily selected. The calculations in the Tables have been made for an effective pressure of 25 lbs. per square inch on the piston, corresponding to a boiler pressure of from 35 lbs. to 45 lbs., a pressure which is very usual for such engines in collieries.

TABLE I.

TABLES of POWERS, &c., of the SINGLE-CYLINDER DIFFERENTIAL EXPANSIVE PUMPING ENGINE.

Diameter of Cylinder.	Length of Stroke.	Effective Horse-power.	Units of Work.	Piston Speed $= \sqrt{L} \times 80$.
in.	ft. in.			ft.
12	1 8	8·56	282,500	100
14	2 0	12·82	423,225	110
16	2 0	16·75	552,750	110
20	2 0	26·17	863,775	110
20	3 0	30·93	1,020,825	130
24	3 0	44·54	1,469,975	130
26	3 0	52·28	1,725,425	130
28	3 0	60·63	2,001,025	130
28	3 6	69·96	2,308,875	150
30	4 0	85·67	2,827,200	160
35	4 6	120·26	3,968,662·5	165
40	5 0	161·83	5,342,550	170

TABLE II.

COMPOUND DIFFERENTIAL EXPANSIVE ENGINES.

Diameter of large Cylinder.	Length of Stroke.	Effective Horse-power.	Units of Work.	Piston Speed $= \sqrt{L} \times 80$.
in.	ft. in.			ft.
20	3 0	24·74	816,660	130
25	3 6	44·61	1,472,400	150
30	4 0	68·53	2,261,760	160
35	4 6	96·21	3,174,930	165
40	5 0	129·46	4,272,440	170
45	5 6	173·49	5,725,440	180
50	6 0	226·10	7,461,300	190
55	6 6	287·97	9,503,200	200
60	7 0	359·85	11,875,080	210

This Table is calculated for an effective pressure, or load on the large piston of 20 lbs. per square inch.

The single-cylinder engines, a pair of which were constructed by Messrs. Hathorn, Davis, and Campbell, for the Clay Cross Collieries, are in use underground, and are employed in pumping the water direct to the surface. They pump against 1000 feet

head of water, whilst a similar pair at Newton Gap have 240 feet. This method of pumping in collieries is becoming very usual, and where there is no chance of the engine being flooded it is probably the best, and certainly the most economical plan, as regards first cost. The construction of these engines is similar to that of the compound engine, minus the high-pressure cylinder. The compound engine just described is placed above ground, whereas these engines are placed below, and are self-contained on one bed plate, with the pumps.

The larger pair of engines is provided with a condenser. It is not, however, a part of the engine, but is entirely distinct, the air pump being worked by means of a small hydraulic engine from the pressure in the main column. In a more recent design the author has put the air pump on the bed with the engine, and worked them by means of a tail rod from the main piston, the pumps being placed both in front of the cylinder, with a plunger common to both barrels. Very severe tests have been imposed on the differential expansive engine by suddenly throwing off the load when the engine is in full work, with the stop valve wide open, this has been done with impunity; there is therefore security against accident resulting from the breaking of a spear, the falling of a pump pipe or a valve, fruitful sources of breakage with the ordinary pumping engine.

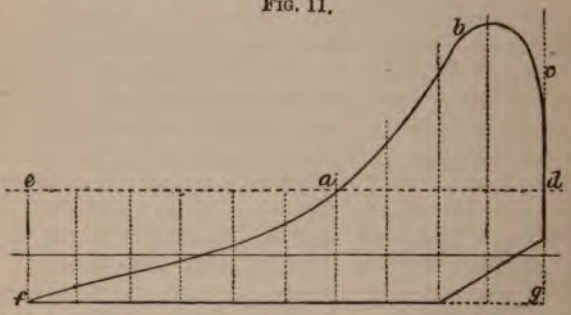
Dip workings in mines are not easy, and are very expensive to drain by means of pumps driven from the main rods, especially where the dip is but little; nor is it always possible or expedient to use a steam pump. The pump may be flooded, and thereby rendered useless, making it necessary to put down other means of getting out the water. To meet these difficulties the late Messrs. Carrett, Marshall, and Co. introduced the hydraulic pumping engine which is illustrated at Figs. 7 to 10. These engines are now made by Messrs. Hathorn, and consist briefly of a hydraulic direct-acting engine and double-acting pump. The mode of application may thus be described:

The engine is placed at the bottom of the dip, a supply pipe is carried to it from the main column, and the delivery pipe from the pump is led to the main sump. The construction of the engine will be readily understood from the engravings. These engines have been fixed in various collieries. A diagram taken from one of the engines at the Clay Cross Collieries shortly after it was put to work shows that the engine did 80 per cent. of the theoretical duty. The dip became flooded from an accident, and the engine was under water for two months, but it continued working the whole of the time, although it could not be seen. For general purposes requiring motive power underground there is a wide field for the employment of water

pressure from the main column or from the tubbing, and the use of the hydraulic dip pumping engine seems a step in the right direction. In whatever way the supply to the engine is secured, whether from the column or from the tubbing, an equivalent of work is added to the main pumping engine. If all the various underground work were done by hydraulic engines, the main pumping engine would necessarily require increased power proportionate to the work done by these engines. The author does not see any great obstacle to the practical application of hydraulic engines for hauling purposes as well as for pumping, thereby dispensing with all boilers and steam pipes in the pit.

In the former part of the paper the author contended that there are difficulties encountered in using steam very expansively in non-rotative engines which render the adoption of the compound system expedient if not imperative. Other reasons besides those already advanced may be brought forward. Fig. 11, which is shown below, is a diagram taken from a Cornish engine. The line drawn horizontally through the diagram cuts the expansion line at the point of average pressure, making the area *a, b, c, d,* equal to the area *a, e, f.*

FIG. 11.



It is evident that if the diagram was produced by a constant force overcoming a constant resistance it would take the form of the parallelogram *e, f, g, d,* but under such circumstances the steam would not be expanded. In the Cornish engine the load lifted is a constant quantity, and that steam can be at all expanded on the piston is due to the fact that the moving load is a mass of matter and not merely an opposing force. The expansive force of the steam can be utilized because the mass in being changed from a state of rest to that of quick motion, absorbs or stores up an amount of energy which is expended during the second change from quick motion to the former state of rest. In other words, during the first change energy, represented by the portion of the diagram *a, b, c, d,* is accumu-

lated, and this energy, which is also represented by the area *a*, *e*, *f*, is during the second change expended. The energy of the mass equals $\frac{Wv^2}{2g}$, and the energy represented by the area *a*, *b*, *c*, *d*, equals the mean pressure of that portion of the diagram multiplied by the distance *a*, *d*, and the resultant multiplied by the area of the piston, making in the present example 150 foot-tons. It is evident that the energy of the mass must equal this energy to produce the diagram; it is also evident from the above formula, viz. $\frac{Wv^2}{2g}$, that at about 500 feet per minute piston speed energy = W; therefore, to produce the diagram the mass to be set in motion at about 500 feet piston speed must be 150 tons. The author knows that to be about the weight of the moving mass in the practical example which he has selected. The load on the piston is not more than 50 tons, and if the engine had no mass to set in motion beyond the column of water to be lifted, the required velocity of that mass necessary to give it the required energy would be beyond all practical limit. On the other hand, if the velocity of the mass is limited to 4 feet per second, then the required mass would be about 600 tons; although the expansion is only about 6 to 1.

If this engine were to be made double acting and employed to lift water on the steam stroke it would be expedient, for practical as well as theoretical reasons, to limit the piston speed to 4 feet per second, making it necessary, as the author has already shown, to provide a moving mass of 600 tons, but with the compound engine, working under similar conditions, only a very small moving mass would be necessary, because the variation in the effective pressures during the stroke would be comparatively very little. An expansion of four times in a single cylinder would give a variation of 4 to 1, but in a compound engine only 2·28 to 1. The reasons for this are obvious. The Cornish engine is a very costly machine; it is only single acting, and it requires a great moving mass to make it practicable to employ a high degree of expansion; nor can it be made double acting without either making it necessary to increase the mass beyond a practical limit or to employ a low ratio of expansion involving a great waste of fuel. To meet these difficulties the author designed the compound differential expansion engine, in which expansion may be carried to a great extent with a piston speed not too great for actuating pumps during both strokes, nor requiring a heavy moving mass, making it practicable to secure economy of fuel with a comparatively small outlay of capital. The differential valve gear is illustrated at Fig. 12, which shows it as applied to a compound engine.

The main slide valves J J receive their motion from a lever to the centre E, to which they are connected. This lever receives two motions, one at the end V derived directly from the main moving parts of the engine by another lever of the first order, which, receiving the full motion of the piston at the long end, imparts from its short limb to the end V of the lever the amount of motion suitable to the working of the valve; and another motion derived from a subsidiary piston X. This subsidiary piston receives its motion from the steam in the main slide chest by means of a small valve Z, and gives motion to a cataract piston Y working in a cylinder filled with water which escapes from side to side through small openings that can be regulated at pleasure by means of the valve K. This cataract regulates the speed of the piston X, and consequently the motion of the end E of the lever F to which it is attached. The valve Z, admitting steam on the subsidiary piston X, is actuated by means of a lever B C to which it is attached at B, and this lever, usually fixed at A, receives motion from the lever F V by the connecting link D C. When it is required to start the engine motion can be given to the valve Z by removing the pivot at A of the lever C A and moving the lever by hand.

The action of this gear upon the motion of the engine will be best understood by an illustration: Suppose the main piston to be at rest at one end of the cylinder, then to start the engine, steam would be admitted by hand into the subsidiary cylinder X, and motion would be communicated to the valves J, and the engine would commence its stroke; as it moves, however, it is giving motion to the lever F V in a contrary direction to the motion communicated by the subsidiary piston X and cuts off the steam. The main valve therefore has a differential motion, compounded of the motion derived from the direct action of the main cylinder, and an opposite motion from the subsidiary piston. Now, the motion of this subsidiary piston is rendered constant by means of the cataract Y. Seeing, then, that the cataract end F of the lever has a constant motion independent of the engine itself, and that the other end V must needs have a varying motion depending on the varying load on the engine, then the resultant motion of the main valve, being taken from the centre of the lever and compounded of a varying and a constant motion, must also vary with every variation in the motion of the main piston.

DISCUSSION.

Mr. V. PENDRED said that Mr. Davey had opened, indirectly, two subjects which had been well discussed by engineers. The first of these subjects was the relative merits of different

systems of pumping engines; and the second was the whole question of steam-engine economy. There were, however, one or two special points on which he (Mr. Pendred) would only casually touch. He had understood the author to state that this pumping engine rendered a variable expansion of eight times with a resulting strain upon the parts of the machinery equal to what would take place if the steam had been cut off at about three times in the cylinder. He had introduced the compound engine. Perhaps no subject had ever been more keenly discussed among engineers than the relative merits of compound and non-compound engines. If the point were argued on theoretical grounds Mr. Davey would be the first to agree that expansion carried out in a single cylinder was theoretically right, inasmuch as the highest possible amount of economy was obtained from that. There were certain conditions, however, under which it was utterly impossible to carry out expansion in the single cylinder; and those conditions had been very clearly and definitely stated by Mr. Davey, and they applied specially to pumping engines. He (Mr. Pendred) would therefore confine his remarks to pumping engines.

He believed that a cylinder pressure of about 30 lbs. or 35 lbs. was considered as much as it was safe or prudent to put upon a Cornish engine. So long as engineers confined themselves to such pressures, was there anything to be gained by going much beyond three or four, or perhaps, at the maximum, five measures of expansion? He might carry the question a little farther, and ask whether there was anything to be gained under any circumstances in expanding steam more than six times with ordinary pressures? During the last two or three years he had given the subject considerable attention, and he had collected a large number of steam-ship logs, not the result of measured mile trials, but the result of actual practical working. From those records he had found that about as good results could be got from expansion at the ordinary pressure of 60 lbs., with an expansion of six times, as could be got under any other circumstances. He further found in analyzing those logs, and from experiments and investigations which he had himself made, that the best result would be obtained from expansion under any circumstances when the absolute pressure at the moment of exhaust was about 10 lbs., that was to say, if steam was used at an absolute pressure of 60 lbs. it would be expanded between five and six times. Therefore, as Mr. Davey had spoken of a certain advantage being gained by expanding eight times, he (Mr. Pendred) should like to know what was the precise gain in expanding eight times instead of three.

The author had opened up the whole question of the economy

of fuel, and he had referred to the records that were kept as to the economy of fuel in Cornwall. He had assumed—and no doubt with very good grounds for the assumption—that part of the notorious falling off in the economy of fuel in Cornwall was due to the cutting down of the expansion. He (Mr. Pendred) believed that, although that statement expressed part of the truth, it did not express the whole truth. He believed that in old times the fuel was of a great deal better quality than that of the fuel used at the present time, and that made a very marked difference. He had no doubt that a great many of those present had carried out trials with coal, and had seen the differences that were brought about by it; but he doubted whether engineers generally realized what the difference was which might be brought about by using two different qualities of coal, both of which were very probably the best of their kinds in the market. He had recently carried out some trials on a horizontal engine with a 21¼-inch cylinder and 36-inch stroke. The engine was guaranteed to work up to a certain duty, namely, 2½ lbs. of coal per horse-power. The engine was supplied with steam by two Lancashire boilers, with 3-feet flues 28 feet long, and grates 3 feet wide and 3 feet 6 long. In the first experiment the grates were 3·5 feet long. The engine was guaranteed to work up to 2½ lbs., with a cut-off at one-tenth. In the first trial the pressure was limited to 60 lbs. instead of 70 lbs., and this trial was made with Gawber Hall coal. He was told by those who were associated with him in the experiment that the boilers were expected to evaporate 10 lbs. of water per pound of coal. He (Mr. Pendred) replied that he knew something of the coal that was going to be used, and the boiler, if properly set, would evaporate 7½ lbs. of water per pound of coal. The water was very carefully weighed out in tanks, and the experiment lasted six hours and was conducted with the utmost possible precaution. The result was that the evaporation was 6·9 lbs. The boilers were very good and well set. He (Mr. Pendred) need not say that the engine did not perform the duty that was guaranteed.

Another trial was made more recently, and he recommended a change of coal. There was also a change made in the grates by their being shortened. On the second occasion the coal used was a South Wales coal, such as was being used on the Metropolitan Railway. With scarcely any alteration in the engine or conditions of working, the consumption of fuel was brought down to 2·6 lbs. of coal per horse-power per hour; and the evaporation was raised to 9·8 lbs. and a fraction over. That was an example of what a very ordinary change in the fuel . On comparing the duties of engines estimated at

different periods, it should be borne in mind that there were differences in the quality of coal. A point worth mentioning was that the quality of the coal used for boilers was falling off, and that instead of the good, sound, free-burning coal that was used in former times, very much slack was used now. Besides, he imagined that in former times more care was taken with Cornish boilers than now. He believed that there were not such bad boilers in the world as existed in Cornwall. A friend of his, upon visiting, some time ago, a mine which was stopped for repairs to the engine, found a man in one of the boilers digging out the mud with a spade. Under such circumstances they could not expect a high evaporating duty from the boiler. Steam gauges were, he believed, practically unknown in Cornwall except among a few enlightened engineers. Now and then engineers found out exactly what their boilers would carry, because they had a blow-up.

Mr. Davey had referred to an engine at the United Mines with a duty of 112 millions. That was probably about the highest duty that had ever been done by a Cornish engine, and that engine, Mr. Davey had stated, broke down after it had been some time in use from the additional strain put on it. It would be interesting if Mr. Davey could state the nature of the breakdown,—the initial pressure in the cylinder before the breakdown,—the initial pressure after the breakdown,—the grade of expansion when it was worked subsequently,—and the duty in the consumption of coal after the engine was put on the reduced grade ef expansion.

Mr. A. Rigg said that it would be interesting if Mr. Davey would explain the action of the valves with the load off, when such a case occurred as the breaking of pump rods. They were very ingenious, and the cataract arrangement seemed well calculated to control the engine that it should run quietly and steadily. The manner in which the variation of the load varied the supply of steam was not very easy to follow at first sight, but the model made that action clear. One or two matters in construction seemed worth a passing remark. For instance, both the high and the low pressure cylinders were fastened firmly to the bed between snugs upon it outside the ends of their flanges, and when the cylinders expanded, though the bed did not expand, there must be great strain, which was generally avoided by placing the snugs inside instead of outside the cylinder brackets. Lignum vitæ slide-valves had been mentioned in connection with hydraulic engines, and it would be interesting to be informed by Mr. Davey under what pressure they were used, and the extent of their durability, as slide valves of hydraulic engines, especially those working at very high pressures, were

liable to great wear in consequence of the disproportion betwee
their wearing surfaces and the pressures they had to resist.

Mr. DAVEY, in reply, said that with reference to Mr. Pendred
first question as to whether anything could be gained by e
panding more than three or five, or at most six times, he (M
Davey) had advocated in the paper an expansion of about eig
times, but he had omitted to give the initial pressure propos
The initial pressure in that case would be from 60 lbs. to 70 l
boiler pressure, and would probably give about 60 lbs. above t
atmosphere as the initial pressure in the cylinder,—in rou
numbers 70 lbs. For the sake of comparison he had rough
calculated a table of the units of work due to different grad
of expansion, and he had assumed an initial absolute pressure
100 lbs. With no expansion the work done was 63,000 un
That was taken as a basis. An expansion of 1·25 would ra
the quantity to 77,000 units, with a fourfold expansion 2·4, a
eightfold expansion 3·3, the amount of work could be do
theoretically. An initial absolute pressure of from 70 lbs.
75 lbs. expanded eight times would bring the terminal press
to something like that advocated by Mr. Pendred, namely, fr
9 lbs. to 10 lbs. He agreed with Mr. Pendred that there w
not much to be gained by expanding steam beyond nine
ten pounds absolute pressure. A higher grade of expansio
was only advisable when the initial pressure was raised. In
speech recently made by Mr. John Hocking, of Redruth, one o
the first mining engineers in Cornwall, he pointed out that th
average duty of Cornish pumping engines formerly was 69·
millions against 50·2 millions now. In fact, 30 per cent. mo
coal was used now than then—thirty years ago. Mr. Hockin
said he believed the lower duty was chiefly due to the lower ra
of expansion, but he did not think the higher rate of expansio
would be resumed. Secondly, he held that the boiler power w
insufficient. Thirdly, that the enginemen were often inefficie
and that premiums should be offered for saving coal. Fourthl
by the present system of working a fair rate of expansion co
not possibly be reached. Fifthly, there was a lower quality
coal. That bore out Mr. Pendred's statement with respect
the coal. As regarded Taylor's engine at the United Mines, I
(Mr. Davey) indicated the engine some time since. The engi
was, at one time, working with a tenfold expansion, and t
initial pressure was about 60 lbs. above the atmosphere wi
from 60 lbs. to 65 lbs. boiler pressure. The boilers were usual
fixed close to the engine, so that nearly the whole boiler press
was brought upon the engine. The engine broke down beca
of the enormous strain thrown on the pump rods. That wor
the joints until the bolts got loose, and the joints became sh

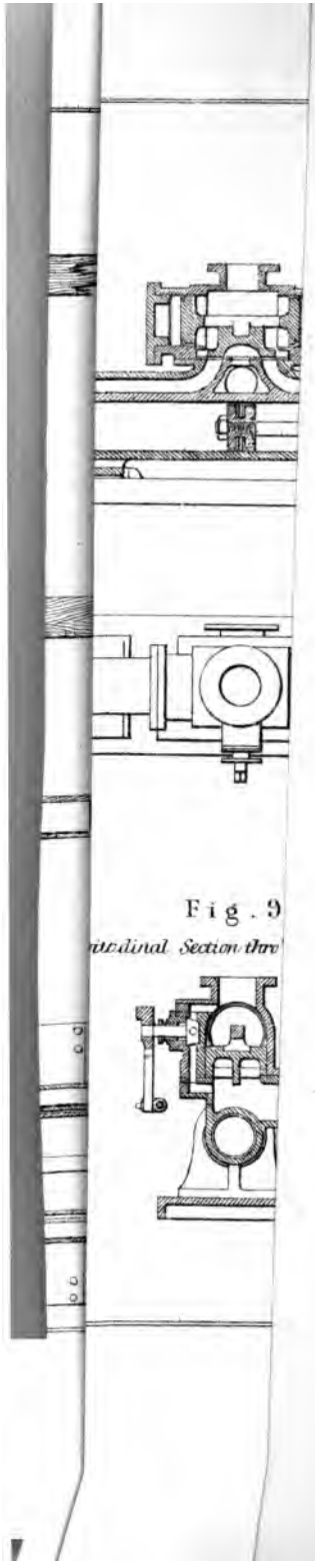
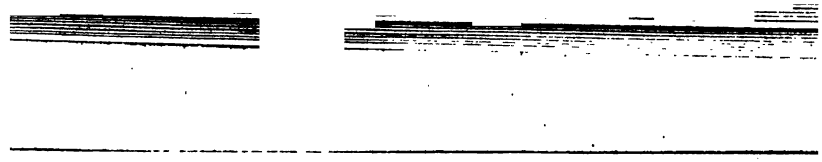


Fig. 9

itudinal Section thro'



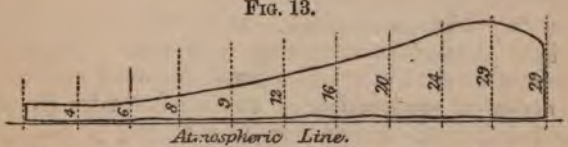
and at last one of the lower spears broke off suddenly, causing the engine to come in with such a crash that it smashed the spring beams and the cylinder. Though the crack in the cylinder existed the engine was still at work. The crack was 9 feet long, and it was patched up with iron borings caulked into the jacket. When he indicated the engine it was working at as high a grade of expansion as was considered safe, and it was doing about 60 millions duty. It worked now with a boiler pressure of from 35 lbs. to 45 lbs., which was a very usual pressure in Cornwall. Some years ago there was some excitement in Cornwall about using higher pressures, and in several instances pressures from 60 lbs. to 70 lbs. were tried; but he believed that the high pressures and high grades of expansion had been discontinued, because a little accident, such as the dropping off of a bucket from the bucket lift, was quite sufficient to make the engine come in with such a crash as to carry everything before it

Mr. Rigg had asked for further information as to the valves of the differential engine. He (Mr. Davey) had that day taken a diagram from a single-cylinder engine with the differential gear upon it, and in which the load had been varied considerably by the opening and shutting of sluices. The effect was shown on the diagrams, Figs. 13 and 14, appended.

DIAGRAM taken from DAVEY'S DIFFERENTIAL EXPANSION PUMPING ENGINE at the SUDBURY WATERWORKS.

Load Constant.

FIG. 13.

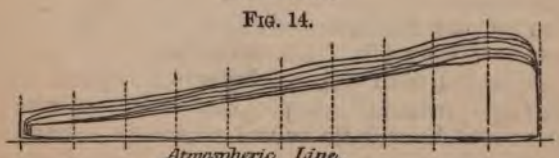


Diameter of cylinder, 16 in.; Length of stroke, 2 ft. 6 in.; Number of strokes per minute, 16.

DIAGRAM taken from DAVEY'S DIFFERENTIAL EXPANSION PUMPING ENGINE at the SUDBURY WATERWORKS.

Load Varied.

FIG. 14.



Diameter of cylinder, 16 in.; Length of stroke, 2 ft. 6 in.; Number of strokes per minute, 16.

November 3rd, 1873.

JABEZ CHURCH, PRESIDENT, IN THE CHAIR.

THE ECONOMIC USES OF BLAST-FURNACE SLAG.

By PERRY F. NURSEY.

There was a time in the history of the arts and manufactures —and that time is well within the memory of the youngest member of the profession—when every department had what were termed its waste products. In some instances this waste was an unconscious one, unrealized by those whom it most affected. In others, however, manufacturers possessed a knowledge of their loss, but strove in vain to lessen or prevent it. Especially was this the case in metallurgical science, where, almost from the first, the value and usefulness of many waste products were fully recognized, and where continued efforts were made to utilize them. It is but a few years since that the gases of the blast furnace were truly yet regretfully looked upon as waste, but for which at length inventive talent found a profitable application. And so in other departments of manufacture, the rapid development of mechanical and chemical science has led to the successful application of waste substances in directions previously but little hoped for, if not wholly unthought of. And thus to-day finds some of the most simple of our industrial processes, each the parent of a variety of others, all more or less beautiful in their conception and happy in their practical results; all tending to promote and sustain commerce, and to enrich the nations of the world. Witness the ultimate results of the destructive distillation of coal, or the more recent perfect utilization of the hitherto valueless waste produced in the manufacture of spun silk. The term "waste products" is now all but expunged from the vocabulary of applied science, and that of "bye-products," so pregnant with meaning, has by common consent become its valued substitute. Manufacturers, instead of seeking how best to rid themselves of what they in their ignorance deemed a nuisance and an incumbrance, are now for the most part busied in devising methods for its careful

retention, with the view to its ultimate conversion into substantial profit.

One of the most expensive, cumbersome, and, until recent years, useless products in the metallurgy of iron is the slag of the blast furnace. The yield of this substance from the Cleveland blast furnaces is about half as much again as that of the iron produced, whilst its bulk is more than three times greater than that of the metal. In the hematite districts the proportions of slag and iron are about equal. This mass of material absorbs and radiates an enormous amount of waste heat, which is so much loss of power. Hence attempts have been made to utilize the heat thus wasted, but without success. It is a heavy incumbrance, inasmuch as large tracts of land have to be purchased whereon to deposit it, the investment being of course wholly unremunerative. One iron manufacturing firm at least within the author's knowledge is exempt from this tax upon its capital, and that is the Hudson Ironworks in the United States, where the slag is used to fill in shallow bays. Thus, instead of having to purchase land for the deposit of the slag, the latter is actually utilized for the formation of land. Again, it is a source of great inconvenience at the blast furnace, accumulating there as it does in a hot viscous mass, difficult to handle, and requiring special tools for removal. In fact, the labour spent upon this unproductive substance often equals the whole productive labour of the blast furnace. No wonder, then, that from the first persistent efforts have been made either to utilize it or to get rid of it altogether. The variety of schemes proposed for either or both of these purposes has only been equalled by the ingenuity displayed in devising them.

The refractory character of blast-furnace slag pointed it out in very early times as a suitable material for road-making, and it was thus first used, being broken up by hand for the purpose. But the demand in this respect is comparatively limited, and falls so infinitely short of the supply, that our slag heaps have gone on steadily increasing in bulk until at old-established works they have attained enormous proportions. In some Continental States, where stone is scarce, slag plays a prominent part in road-making, where it can be procured in large quantities. In Silesia, and other similarly situated countries, careful attention has been devoted to the treatment of slag in order to render it as suitable as possible for road-making, being the only available material for that purpose. The great brittleness of slag is one of its objectionable features, so that in the first instance attempts were made to devitrify it. This implies a supply of cheap fuel, otherwise the process would prove too costly. As cheap fuel is scarce, devitrification is in

some places successfully effected by allowing the slag to accumulate around the blast furnace, and to cool slowly under considerable pressure. This method is adopted at Tarnowitz and other districts in Silesia, where the slag accumulates to a thickness of 18 inches before removal. The process is, however, imperfect, only the lower half becoming devitrified; but it nevertheless furnishes a good road-making material.

Another direction in which attempts have been made to utilize slag is to adapt it for constructive purposes. In the Cleveland and some other districts the slag is run into moulds and afterwards used for foundations, embankments, reclaiming land from the sea, and for similar purposes. In the Black Country the author has seen walls, and even houses, built up of moulded slag blocks, and they have in some instances presented a very pleasing appearance, owing to the variegated nature of the slag. But in all these cases there is a limit to the application, whilst there at present continues to be no limit to the supply of the material. Attempts have been made to utilize slag for ornamental purposes, by running it into moulds and afterwards annealing it; but the latter process was found to be too costly, and this anticipated source of relief proved to be but one of disappointment.

In some Continental countries building stone is very scarce, and as slag appeared to contain the elements of a good building material, it was submitted to seemingly endless experiment, attended by apparently endless failure. In time, however, success came, and the result was the production of a very useful material for certain kinds of construction. The process of manufacture as carried out at Königshütte, in Silesia, consists in running the slag from the furnace into a hemispherical basin on wheels. The bottom of this basin is covered with sand or fine coke dust to the depth of about 1¼ inch, and the wagon is drawn to the point where the bricks are to be made. The slag and sand are mixed together with a curved iron tool until most of the gases have escaped and the mass is about the consistency of dough. It is then drawn with the same tool into a mould with a hinged cover, and punctured several times to let out the gas. The cover, which fits into the mould, is then turned down, and the slag becomes compressed. By the time three or four moulds have been filled, the first slag brick is sufficiently solid to be removed. This is done by raising a clamp, which allows the mould to separate. The red-hot brick is now drawn into a kiln, covered over with powdered coal and left to anneal. Each kiln contains 1000 bricks, and is from three to four days in cooling. One man can make 500 of these bricks in three hours. The loss in manufacture from breakage is about 20 per cent.

These bricks are rough on their surfaces, but on account of their larger size do not require more mortar than an ordinary brick. They do not readily absorb moisture, and for that reason are extensively used in the construction of foundations. In Silesia these bricks cost 25 per cent. less than an ordinary brick.

In the Hartz mountains the lead-furnace slags, which are silicates of iron, are run into moulds and compressed, thus forming bricks for building purposes. They are, however, of inferior quality, being very brittle, and houses built with them are usually coated with compo. One of the first successful attempts on the Continent to transform slag into a useful building material was that made by M. Sepulcre, a Belgian engineer. His process consists in running the slag into pits having the sides inclined at an angle of about 30 degrees. This quick increase in the sectional area of the pit allows the solid crust which forms on the top of the slag to rise with it without becoming attached; the whole mass of slag is thus liquid, and solidifies from above and under pressure, being left several days to cool. When first turned out the stone thus produced can be readily broken into any required shape; but it gradually hardens on exposure to the atmosphere. The primary conditions of success with this process are that the furnace is in good working order, and that the slag contains about 40 per cent. of silica. If lime be present in excess, the stone will crumble to pieces on exposure. From experiments made by the "Conservatoire des Arts et Métiers," in Paris, with the stone produced by M. Sepulcre's process, it was found that when made from the slag of grey iron it became fissured at a pressure of 3100 lbs. per square inch, and was crushed under 5700 lbs. Stone made from white iron showed fissures at 3450 lbs., but it did not give way until a crushing strain of 12,600 lbs. per square inch had been reached.

Another application of blast-furnace slag on the Continent is that of glass manufacture. In Belgium experiments in this direction proved so successful that it led to contracts being entered into, by the glass manufacturers in some parts of the country, with the proprietors of blast furnaces for the regular supply of slag for this purpose. The only preparation necessary is to run the slag out on to iron plates and to cool it with water. By far the most general method of dealing with slag is to granulate it with the view of its ultimate adaptation to constructive purposes; and this course of treatment is carried out in various ways both in England and on the Continent. When in Belgium a short time since, the author visited, amongst other industrial establishments, the ironworks of M. Dallemagne, at Sclessin. There the slag is granulated in a very simple manner. On being run off from the blast furnace it is made to pass

through a stream of water, which has a sufficient velocity to carry the grains of slag into a pit, from which it is raised and delivered into wagons by an endless chain with buckets attached. The water enters under the slag and the steam formed at the junction of the two is said to materially assist in breaking up the slag. The only labour required is that of a couple of boys, who occasionally agitate the mixture of slag and water, one at the point of entrance and the other near the buckets. The invention of this simple process of disintegrating slag, which is extensively used in Belgium and France, is said to be due to M. Minary, director of the Franche-Comté Iron Company. In these works, which consist of five blast furnaces, each producing 20 tons in twenty-four hours, the introduction of the system resulted in the saving of the wages of twenty men who were previously occupied in charging the slags, and of five blacksmiths who repaired their tools. The saving effected is from 5000 to 6000 francs per annum. Beyond this saving, however, there is another absolute gain afforded by the utilization of this granulated slag in various departments of the works. The first uses to which granulated slag was there put were as a substitute for gravel, and for making the bed of the casting-house. The pigs came out of these beds very clean and bright, and were preferred by the puddlers even to those cast in iron moulds. This method of using the slag is now of almost universal application in the Siegen district in Prussia, where most of the furnaces run on spiegel. The cleanness of the pigs cast in slag beds suggested its partial application to moulds for fine castings. The fine dust was sifted out from the granulated slag, and with it the moulds were sanded, the result being that the castings turned out better and cleaner than before. As may be supposed these applications only consumed a very small portion of the slag; the surplus was therefore offered to the railway companies, and they find good use for it as a ballast, paying a moderate price for it; the foundries thus obtained a revenue from what had previously been but a source of continual expense. It is stated to make a good ballast; being porous it retains but little moisture and packs very well.

From the first moment that the granulation of slag became ccomplished fact its substitution for sand in construction sted itself, and its use in this respect has been attended ery good results. It was first mixed with lime and used nortar, and some having been left from a job was soon ards found to have become very solid. This was suggestive ther applications—the preparation of concrete and the ruction of foundation walls. To both of these purposes it been lly applied. Then followed the idea of manu-

facturing bricks, and the proprietors of the Georgs-Marienhütte, in Hanover, mix the granulated slag with lime, press and sun-dry the bricks moulded therefrom, and have used them very largely in the construction of their buildings. They cost much less than the ordinary bricks, and being almost white give a light, cheerful air to the buildings. Another application of granulated slag consists in coating the surfaces of unburnt bricks with it, and burning them out of contact with coal. This produces an enamelled face—an appearance which is much sought after in some places on the Continent. By the admixture of slag sand with fire clay the quality of the bricks made therefrom is said to be greatly improved. This suggests the application of the sand in the manufacture of bricks for puddling furnaces, where a highly refractory material is still a desideratum. The possibility of manufacturing cement from granulated slag has been demonstrated at one of the largest ironworks in Germany, where experiments were carried on for several years with the view of determining the point. Large works have been constructed in connection with this foundry, where an artificial cement is manufactured which is said to be equal to the best Portland cement, and which is produced at a very low price.

The important part which carbonic acid plays in rendering soluble the various mineral substances required by plants for their growth, has led to the supposition that blast-furnace slags can be profitably employed for agricultural purposes. Whether German ingenuity has succeeded in the successful application of slag in this respect the author is not aware. That English skill has not been able to effect the object he is aware, as will presently be shown. Hitherto the author has confined himself mainly to the theory and practice of Continental metallurgists in the matter of the utilization of the slag of blast furnaces. He will now proceed to deal with the practical development of the question in England, noticing *en passant* such proposals bearing on the subject as are of interest or value. In this, the home department, as it may be termed, the author is able to supply information of a more precise and detail character, and to show by diagrams and models the exact form of apparatus used in producing given results, which results, moreover, are themselves illustrated by samples of the various products.

Amongst the earliest scientific investigators of the question of applying furnace slag to economic purposes was Mr. Bessemer, one of our honorary members. In the year 1863 Mr. John Gjers, of Middlesborough, also a member of our Society, patented a plan for granulating slag by running it into agitated water. The sand thus produced was used in place of siliceous sand on

the pig beds. Mr. Gjers, however, informs the author that he gave up the practice because in Middlesborough no cover is used over the pig beds, and in wet weather some trouble was occasioned by the slag absorbing and retaining water. Moreover, sand is very cheap in that part of the country, and the iron-masters there failed to appreciate the advantages of having a good flux on their pigs rather than a siliceous sand covering, which does not tend to promote good yield either in the puddling or the cupola furnace. With covered pig beds Mr. Gjers experienced very good results.

In 1871 Mr. David Joy submitted to the iron trade of Cleveland a plan for shipping slag in blocks, differing somewhat from a plan proposed by Mr. Charles Wood a year previously to the Tees Conservancy Commissioners, not only for taking the slag to their breakwater, but also for removing it direct from the furnace by an endless band. Simultaneously with this a similar plan was projected by Mr. Thomas Bell, and soon after practically worked at Walker. Messrs. Smeeton and Bowler, Mr. Lurrman, and Mr. Homer also deserve honourable mention for the active part each has taken in promoting the solution of the slag difficulty. But, perhaps, no names have been more prominently before the public of late years in connection with the subject than those of Mr. Charles Wood of the Tees Ironworks, Middlesborough, and Messrs. Bodmer of the Spring Vale Brickworks, Hammersmith. Mr. Wood has designed and brought into successful operation machinery for the granulation and disintegration of slags, whilst Messrs. Bodmer, taking the results of Mr. Wood's process, have been no less successful in utilizing them for constructive purposes. Messrs. Bodmer have also devised a special method of reducing slags to a state of division of various degrees of fineness. Mr. Wood's disintegrators are of two kinds, horizontal and vertical; the former is used for reducing the slag coarsely, and the latter for producing a fine slag sand. Fig. 1 represents a plan, and Fig. 2 a sectional elevation of the first of these, which Mr. Wood terms a slag-cooling machine. It consists of a circular revolving table composed of thick slabs of iron. The table is kept cool by means of water which circulates through channels formed in the slabs. A set of scrapers are attached to a fixed arm carried above the table. The table is made to revolve very slowly and the liquid slag is delivered on to it, and forms its own thickness, varying from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch. As soon as the slag has parted with sufficient heat to become solid, water is allowed to run freely upon the surface, and by the time it arrives at the scrapers it is sufficiently cool to part from the table readily and break t then drops into the slag wagons, and as

each wagon is filled it is removed and another takes its place.

The slag-sanding machine is the reverse in principle of that just described: Fig. 3 is vertical section, Fig. 4 a side elevation, and Fig. 5 a transverse section of this machine, which in shape somewhat resembles a rotary puddler. Its sides, however, are only made sufficiently high to enable it to contain from 2 feet 6 inches to 3 feet of water in the bottom. This cylinder is kept in motion by a small steam engine, and the water is agitated by means of buckets placed inside the periphery of the cylinder. These buckets are perforated so as to act as screens, to separate the sand from the water. They also elevate the sand to the top of the machine, where it drops into a spout, and is conducted thence into wagons. The speed of the machine is about 100 feet per minute, or about four and a half or five revolutions, according to the nature of the slag. Thus, the water is kept in a violent state of agitation, and the liquid slag, which is run into it direct from the furnace, is instantly scattered in the body of water in the form of sand, the water taking up the heat and throwing it off again in the shape of steam. The action of the machine is so perfect that no crust nor any large pieces are allowed to form. On the table are samples of this slag just as it comes out of the machine. The slag is delivered in a constant stream into railway trucks, in a suitable condition for being dealt with for manufacturing purposes.

The next point for consideration is the manner in which the material thus produced is converted into a commercial article. There are four chief purposes to which granulated slag is applied: these are the manufacture of bricks, mortar, concrete, and cement, and chief amongst those who have persistently devoted themselves to the question of utilizing slag in these respects are Messrs. Bodmer and Co., who take up the question exactly where Mr. Wood leaves it, and so carry out the ultimate application of the slag in practice. After proving his machines to be a success, Mr. Wood sent some of the slag sand to Messrs. Bodmer, who, by mixing eight parts of the granulated slag with one of cement, produced a valuable brick, specimens of which are on the table. By Bodmer's process the sand requires no further manipulation than the mixing it with lime, and submitting the compound to hydraulic pressure. After two or three weeks' exposure to the air the bricks are found to be fit for use. In making mortar Mr. Wood uses five parts of the sand to one of lime, which, when well ground up together, form an excellent mortar, nearly equal to cement. By adding about 5 per cent. of ironstone to the mass Mr. Wood has found that the strength of the material is greatly increased. Concrete is

made by combining six parts of the rough slag from the first machine with one part of the mortar just described. The materials are worked up well and moulded into blocks, which are found to be very suitable for foundations and for the walls of cottages. Concrete made from Mr. Wood's rough slag mixed with Portland cement has been extensively used in carrying out the drainage of Middlesborough; and, as far as the author is informed, its use has proved very satisfactory. The manufacture of cement from slag has also been attended with good results, as will presently be shown.

An important consideration in determining the commercial success of any invention, and one to which the practical mind intuitively turns at the outset, is that of cost. It is satisfactory to find that in the utilization of slag for the purposes mentioned the question of cheapness in production has been placed beyond doubt, as shown by the following statement of facts, which have been compiled from actual working, and communicated by Mr. Wood to the author:

SLAG SAND.

Taking the make of the furnace at 25 tons of iron, there would be a yield of about 36 tons of slag. To convert this into sand the expenses would be—

	s.	d.	
One man, per day	4	0	} per shift.
8000 gallons (water) at 3*d.*	2	0	
Wear of machine	3	0	
	9	0	× 12 ÷ 36 = 3*d.* per ton.

Concrete Blocks.

		s.	d.	
Rough machine slag, 8 tons		4	0	
Slag mortar .. .. 1 ,, ...		4	0	
9 ,, ..	=	8	0	
Labour, 1*s.* per ton		9	0	
		17	0	÷ 9 = 1*s.* 11*d.*

1*s.* 11*d.* per ton, or ¾*d.* per cubic foot. If with ironstone, about 1*d.* per cubic foot.

Mortar from Slag Sand.

		s.	d.		s.	d.
5 tons sand, at 3*d.*		1	3			
1 ton lime, at 15*s.*		15	0			
6		16	3	÷ 6 =	2	8
Grinding					1	4
					4	0

Four shillings per ton.

Bricks.

	s.	d.
2 tons 10 cwt. of slag sand at 3*d.* per ton	0	½
Lime	4	0
Wear of machine	1	3
Coals and water	1	0
Labour, &c.	3	2
Per 1000	10	0

The following analysis of blast-furnace slag has also been furnished by Mr. Wood to the author:

Analysis of Furnace Slag.

Silica	38·25
Alumina	22·19
Lime	31·56
Magnesia	4·14
Protoxide of iron	1·09
Manganese	trace.
Calcic sulphide	2·95
	100·18

The author has already referred to the part taken by Messrs. Bodmer in converting the slag sand produced by Mr. Wood's machinery into bricks. But Messrs. Bodmer have done more than this; they have designed a system of slag reduction upon what may be termed the dry principle in contradistinction to that of Mr. Wood, which is on the wet principle. This system had been perfected after protracted experimental working at blast furnaces in Wales. A careful investigation into the properties of slag produced in the wet way led Messrs. Bodmer to the conclusion that there were conditions to which slag so treated was inapplicable. They found that sand obtained by running the slag into water consisted of large and small granules of a spongy porous character and very light. Carefully examined it would seem that the water causes the slag to form agglomerations of cellules, each of which encloses a certain amount of moisture. When heated the moisture becomes converted into steam, which does not escape, but re-condenses upon the temperature being lowered. It is found to be practically impossible to dry such sand without previously pulverizing it. This spongy slag, when used as railway ballast, does not readily settle down into a solid compact mass, and hence arises an objection to it in this respect. It is, however, well adapted for certain descriptions of concrete and for brick-making. How far its sponginess affects its resistance to compressive strain, the author is not prepared to state. In

manufacturing bricks from spongy slag-sand, Messrs. Bodmer find it necessary to pulverize the sand before they are able to use it, in order that it may attain the requisite degree of dryness.

The object of Messrs. Bodmer therefore was to produce the sand in a dry condition, and they effect this end by passing the slag through rolls. The slag is delivered direct from the blast furnace into a pair of rolls, revolving either with equal or differential surface speeds. If the object is simply to obtain the slag in a convenient form for removal, the rolls are set wide apart; with rolls working at equal surface speeds the slag is delivered in the form of a continuous band of the same width as the rolls and about ¼ inch thick. The slag is either deposited in a truck direct from the rolls or fed upon a forwarding apparatus, as most convenient. With plain rolls moving at differential surface speeds, or with corrugated rolls, the slag is delivered in slabs. Slag produced in this manner, and without being brought into contact with water, retains its crystalline fracture and hardness, as will be seen by the specimens on the table. This condition is most favourable to its use for ballasting and for the manufacture of concrete. If the slag is required for the manufacture of bricks, mortar, or cement, plain rolls revolving at differential speeds are employed, the rolls being set a greater or less distance apart, according to the thickness of slag scale desired. When the slag on issuing from the rolls is allowed to drop into water, it is rendered amorphous without becoming spongy, and without the capacity for retaining water peculiar to spongy slag. Such slag being very friable, as the specimens on the table show, can be further disintegrated, if desired, with facility. With the rolls placed very close together and with considerable differential speeds a very fine thin scale is produced, especially suitable for the manufacture of slag cement.

In carrying out their process of disintegration Messrs. Bodmer do not employ any special mechanical arrangement. The rolls are of the ordinary type, about 25 inches in diameter and 20 inches in length. Beneath them is a moving shoot by which the rolled slag is fed either on to a chain belt or a bucket belt, which delivers the slag into the trucks. A pair of rolls of the dimension stated will take through about 94 cubic inches of slag ¼ inch thick per revolution, or working at a speed of thirty revolutions per minute, and the slag weighing 120 lbs. per cubic foot, 195 lbs. per minute, or more than five tons per hour. This rate of working is found ample to meet the exigencies of the greatest rush of slag. Messrs. Bodmer's method of preparing the slag has not yet been adopted in practice, but the a[illegible]s informed that a licence to work their patents in the [illegible]orough district has been granted by the inventors

to a company which has been formed in the iron districts for the utilization of furnace slag. The same company has also arranged to work Mr. Wood's patent.

In converting the slag into bricks, Messrs. Bodmer first feed that material into a hopper placed over the measuring apparatus, from which it issues in a uniform layer on a carrier belt. At the same time the lime and other cementing materials are each fed into a separate hopper and measuring apparatus, and upon issuing therefrom are passed together through a mixing apparatus, from which the mixture falls upon the travelling layer of slag sand. The cementing material and the sand are then passed in combination through another mixer, in which they are intimately incorporated. The compound is then delivered on to a travelling belt, by which it is conducted to the brick press. The whole of these operations, with the exception of the feeding of the hoppers, are automatically performed. The brick press is on the hydraulic principle, and is worked by a hydraulic force pump and an accumulator. It consists of a circular table revolving horizontally, and fitted with six pairs of moulds. Whilst four moulds are being filled, four others are under pressure, and finished bricks are being discharged from the remaining four, the processes being carried on simultaneously. The bricks are removed on barrows to the drying sheds, where they remain until ready for use. The time required for ripening is from three to five weeks, according to the character of the lime used, and according also to the weather. The press is worked at the rate of seven strokes per minute, producing therefore twenty-eight bricks per minute, or at the rate of 80,000 per week. For this production two men and four boys are required, exclusive of wheelers and pilers.

A series of experiments were made for ascertaining the degree of absorption possessed by bricks of various kinds. The bricks were dried on a heated iron plate and were then weighed. After having been immersed in water for fifty hours, they were again weighed, with the following results:

	Best Gault Clay Brick.	Best Stock Clay Brick.	Bodmer's & Co.'s Bricks.		
			Sand and Lime.	Blast Furnace.	Slag and Lime.
				Dry slag.	Spongy slag.
	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.
Weighed dry	5 15	4 13	6 9¾	7 7½	5 7¾
Weighed wet	7 2½	5 14⅓	7 1¼	7 12¼	5 14½
Water taken up per brick	1 3¼	1 1½	0 7½	0 4¾	0 6¾
Percentage of water taken up ..	20·26	22·72	7·09	3·97	7·69

The manufacture of cement from slag presents several features which are worthy of consideration. A great similarity exists between trass, a cementitious substance found along the banks of the Rhine, puzzolano, and blast-furnace slag, as will presently be seen by the results of analyses. Notwithstanding this similarity it does not appear that furnace slag has yet come into commercial use as a cementing material. It has, however, been made both in England and on the Continent, and has been successfully used by those by whom it has been made. But as far as the author can ascertain it has not yet become a regularly constituted article of commerce in any country. The reason for this appears to lie in the fact that unless the slag is disintegrated under pressure and out of contact with water the material is not in a proper condition for the purpose. Messrs. Bodmer therefore pass the slag through rolls closely spaced, and to produce a reliable cement from it they grind it to an impalpable powder in company with the lime. The slag must be perfectly dry and at the same time friable. The stronger the hydraulic properties of the lime used, the more reliable the slag cement becomes. Practice has, moreover, proved that the slag from a grey iron furnace yields the best results.

The following Table gives the results of some comparative experiments with slag and Portland cements :—

Figures taken from Experiments made on the Strength of Portland Cement by Mr. John Grant.			Experiments made with Slag Cement by Mr. J. J. Bodmer.		
Weight of Cement per Bushel in lbs.	Age after Gauging.	Tensile Strain per square inch in lbs.	One part Lime and seven parts Slag by weight.	Age after Gauging.	Tensile Strain in lbs. per square inch.
106·7	7 days	157·6	..	..	..
107·6	„	156·56	..	..	..
111·75	„	201·63	..	..	..
114·15	„	269·78	..	14 days	271·22
119·04	„	248·03	..	..	..
119·07	„	305·89	..	..	..
121·0	„	409·77	..	..	..
„	14	472·26	..	1 month	470·18
„	28	499·51	..	..	..
„	2 months	522·44	..	..	..
„	3 „	558·62	..	..	..

The results were obtained under tensile strains, and the slag cement was composed of six parts of slag from a blast furnace producing No. 3 foundry iron, and one part of lime of medium hydraulic properties.

The following Table gives comparative analyses of slag cement,

trass, and puzzolano, and shows the similarity already referred to as existing between those substances.

	Blast-Furnace Slag.					Trass.	Puzzolano.
	Cleveland District.			Wales.			
Silica	36·20	40·75	34·00	49·50	45·0	57·	44·50
Alumina	26·	24·47	24·33	15·20	16·42	12·	15·
Lime	27·	24·50	34·	19·70	26·78	2·60	8·80
Magnesia	9·	7·17	5·88	3·	0·40	1·	4·70
Protoxide of iron ..	1·30	2·05	0·07	8·82	5·20	5·	12·
Potash	..	..	..	..	0·46	7·	1·40
Soda	..	..	..	..	..	1·	4·
Sulphur	0·40	0·65	1·72	1·29	..	..	..
Water	..	..	..	..	..	9·40	9·20
Protoxide magnesia	..	..	..	..	5·64	..	..

The applicability of slag to agricultural purposes, to which reference has already been briefly made, is at present very problematical. Although it contains ingredients which in themselves are fertilizers, it is questionable whether these substances exist in the proper form for assimilating with the soil. The lime in the slag, for instance, assumes the form of a silicate, a totally different condition from that in which it is used in agriculture. Mr. I. Lowthian Bell, the President of the Iron and Steel Institute, himself a producer of blast-furnace slag to the extent of about 1000 tons per day, informed the author that, being desirous of utilizing the slag, he granulated some and applied it on land where it was somewhat heavy. On comparing the crops on the land thus treated with those on similar adjoining land not dressed with slag, he could detect no difference whatever. It would, therefore, appear, that as far as this application is concerned, the conditions under which it may be effectively used have yet to be determined.

Another application, which, although it has proved to be more successful than the last, is at present quite as far from being adopted in practice, is that of a clothing for steam pipes. To produce the slag in a proper condition for this singular purpose, a blast of steam, water, or air is forced into the stream of viscous slag as it is run from the furnace. Thus treated the slag assumes a fibrous form similar to spun glass, and is known as "furnace wool." When the stream of slag is imperfectly acted on by the current directed against it small globules are formed about the size of shot. This fibrous slag is a bad conductor of heat, and has been used as a covering for steam boilers and pipes. Slag has also been used for adulterating emery powder.

Such, then, are the principles and practice of slag utilization, as they exist at the present time. The principles can hardly be said to be fully developed, nor the practice much more than in its infancy. Further investigation, for which there is room, will probably be found to modify present principles, whilst extended working will doubtless suggest alterations in practice, and both will add to the discovery of more numerous uses for slag. The author is convinced that these three things will result in time, as a natural consequence of the general desire to promote the economic use of blast-furnace slag, and thus to convert a source of absolute loss into a means of permanent profit. And what is true as regards the utilization of slag holds good also with respect to other substances, which may now be treated as waste. Doubtless the progress of science, in promoting economy of working, will yet lead to the utilization of substances for which at present no satisfactory use can be found. All matter was but so much waste before the creative faculty of man provided appliances for its utilization. And so human progress will further show, that what is now the veriest waste, will, in the course of time, assume a condition of value. Thus will art be made to approximate to nature, in that she will know no waste.

DISCUSSION.

Mr. CHARLES WOOD, in the course of a further description of his process for utilizing slag, said that he did not quite understand Mr. Nursey's explanation of the process carried on in Belgium for making cement. He (Mr. Wood) had made a very large amount of mortar in the Cleveland district, and he had done a quantity of concrete work with it. The mixture contained only one-seventh part of lime, being composed of one part of yellow limestone to six parts of slag sand or the spongy slag. That formed pure mortar. He was now building with that material which was produced by the horizontal machine and mixed with the mortar, which made a concrete and formed a very compact mass. Mortar could be made at 3*s.* 6*d.* a ton, and it was not very much inferior to cements for which 60*s.* a ton was paid in his district. When he read his paper before the Iron and Steel Institute in the present year, Mr. Lowthian Bell made some disparaging remarks upon the application of slag for manure. He (Mr. Wood) had taken a great deal of trouble in investigating that mode of using slag, and during the spring he had sent out in the different districts between 400 0 tons of the slag sand to the farmers in his neighby As far as he had found, it was universally approved,

and vegetation had been most vivid where it had been applied. A gentleman had recently told him that where it had been applied the grass grew to double the ordinary height, and the cattle gathered more than anywhere else. The spongy slag, when examined by means of a microscope, was found to be in a minutely divided state, and when brought into contact with the soil it decomposed. The lime was precipitated; the silica was also precipitated; and the sulphur was liberated and assisted very materially. Wheat straw contained about 60 per cent. of silica, and when wheat was grown year after year on the same land, that silica was never returned to the land. The slag sand contained that very important ingredient, and a marked improvement in the growth of wheat had been caused by its use. The same material had been applied to potatoes, which grew with a beautiful clean skin, and quite free from disease.

The PRESIDENT asked how it was that the iron of the slag was valuable on land. He endorsed the view that silica and lime would be useful, but that would be quite apart from the iron.

Mr. WOOD said that the only iron present in the slag was contained in about 1 per cent. of peroxide of iron, as shown by the analysis which had been given in Mr. Nursey's paper. Many wheat lands contained about 8 or 10 per cent. of iron, particularly the clay out of which red bricks were made.

The PRESIDENT said that, as he understood Mr. Wood, he claimed that the slag, apart from its other advantages, contained 28 parts of silica, 22 of alumina, and 31 of lime, which were substances useful in an agricultural point of view.

Mr. WOOD replied that there was also calcic sulphate—or, in other words, plaster of Paris, or gypsum—and that formed a manure of itself which had been found very valuable; therefore there were four useful manurial ingredients in the slag.

Mr. J. J. BODMER was invited by the President to give some further information about his process. He said that Mr. Nursey had so fully explained it that there was very little to add. The process was very simple. A pair of plain rolls with necessary driving power were all that was required. One advantage of disintegrating slag according to his process was, that it mattered not what the nature of the slag was—whether it was grey or black, and it could be produced either $\frac{1}{4}$ inch or $\frac{3}{8}$ inch thick, or in a perfectly thin scale. There was practically no wear on the surface of the rolls, for the material was plastic. The only water used was that which was passed into and through the rolls to keep them cool, and the same water could be used over again. Besides that, he used water only when he

required amorphous slag—slag which could be easily crushed up. For that purpose he allowed the slag to drop into water from the rolls. But even for making bricks or cement that form could be easily dispensed with, because he could roll the slag so thin that it would work up afterwards as easily as sugar or salt. With reference to the manufacture of cement, he might observe that the spongy slag made a very good cement if it was ground with lime and used at once. It became moist, or, in fact, wet; and if it could be used there and then, it formed first-rate cement, and excellent work could be done with it. But in order that cement might be commercially available, it ought to be in a form similar to Portland cement or ground lime. It could be so produced from the rolled slag, because that material contained no water, and could therefore be ground up perfectly dry. It was capable of forming a much finer powder than Portland cement. The weight of the slag cement was nearly the same as that of Portland cement; and the mixture could be packed in casks and sent about as an article of commerce. The advantage of making bricks with the dry slag was, that there was no trouble in getting the material dry. They could make very excellent bricks with spongy slag; but after the spongy slag was mixed with the lime, a certain time had to be allowed for the lime to take up a portion of the moisture before the mixture could be passed through the press. If that was not done the water would ooze out from the moulds, and inconvenience would result. The dry slag would press better than the other, and fill the moulds more equally. His firm commenced to utilize slag about seven years since, and he believed they were the first to carry out the process in England.

The PRESIDENT asked whether the last speaker meant to imply that moisture deteriorated slag cement in the same way as Portland cement.

Mr. BODMER said that moisture would, of course, cause the cement to set.

Mr. A. WILLIAMS asked whether the slag bricks were burnt in a kiln.

Mr. WOODS replied that the bricks were air-dried, and simply subjected to hydraulic pressure.

The PRESIDENT said that he supposed the slag bricks were not applicable to the purposes to which fire bricks were applied.

Mr. WILLIAMS said that, with 30 per cent. of lime in them, they could not be fit for fire bricks. They appeared to him to weigh one and a half times the weight of the ordinary stock bricks, and consequently would not compare favourably with ' m as regarded carriage.

Mr. BODMER said that a brick produced from the lias lime was very much lighter than any stock brick.

Mr. WILLIAMS said that the weight of one sort of the bricks exhibited was reduced by the brick being hollowed out; but if a wall was built with bricks of that kind, the hollow must be filled up with mortar, or there would be an air space. If there was to be an air space, then those bricks ought to be compared in weight with perforated bricks, and he doubted whether, in that case, they would not be found to be heavier.

Mr. WOOD said he believed that the bricks referred to weighed about 7 lbs. each.

Mr. NURSEY said that he had given the weight of various bricks in the paper. Those made from the spongy slag weighed 5 lbs. 7¾ oz. each, and were lighter than the best gault bricks, which weighed 5 lbs. 15 oz. each.

Mr. WILLIAMS said that it appeared that the stock brick was the lightest. The cubical contents should be taken into account.

The PRESIDENT remarked that the slag bricks were not so absorbent as those made from clay, and therefore there must be more difficulty in the setting of the mortar. That was the disadvantage in the gault bricks. There was no tie or absorption in them, and hence there was an absence of strength in the work. An 18-inch wall made of them might be readily pushed down, and if that was done it would be found that there had been no cohesion.

Mr. WOOD, in answer to various inquiries, said that the slag bricks did not contract in burning. They could be glazed on one side if necessary, but in that case they must be subjected to heat that the glaze might be reduced. They were quite equal to undergoing even a white heat without deteriorating; but the great feature in them was that they did not require burning. Stacking bricks in a kiln, handling them, and consequent breakage, formed a serious cost in the production of ordinary bricks. Slag bricks could be easily made at 12*s.* a thousand at iron works. They required heavy pressure as a means of increasing the atomic contact in the mass and reducing the quantity of lime. It was the chemical action of the lime upon the slag which made the bricks set so hard, and the more the substance was pressed, the more were the atoms of lime brought into chemical combination with the atoms of slag. He looked upon the pressure as being useful in bringing about chemical action by mechanical power, instead of heat.

Mr. A. WILLIAMS said that from the figures given in the paper, it appeared that slag cement improved by keeping.

Mr. F. W. BRYANT remarked that in about a month the strength of the slag cement reached that of the Portland cement.

Mr. WOOD said that he had no tests beyond a month, but he had proofs that the slag cement went on increasing in hardness.

Mr. WOOD, in answer to further questions, said that the price of 12*s.* a 1000, which he had quoted for the bricks, included an ample allowance for breakage, although really the waste was not above 2 per cent. One of them might fall from a height of 100 feet without being broken beyond having a corner knocked off. They would not suffer disintegration by exposure to air. The more they were exposed the harder they would get. That would also be the case if the surface were cut. As far as he had seen, frost failed to affect them. He did not think that even in long continued wet weather they would absorb so much moisture as to be liable to damage by frost. He believed they absorbed less water than ordinary freestone.

Mr. J. J. MILLER asked if the cement would bear mixing with sand in the ordinary proportion, as with Portland cement.

Mr. WOOD said, that if the slag cement was in a dry powder it could then be mixed with sand in the ordinary way, as Portland. In Middlesborough they simply mixed the lime with the slag sand as it left the machine. There was sufficient moisture retained in the slag to wet it; and it was then used directly for building purposes. In less than three hours after it was laid the bricks were so completely set that they could hardly be knocked off with a trowel. Mr. Bodmer, in his process, ground the dry slag and mixed it with lime, and then sold it already mixed.

Mr. NURSEY, in replying upon the discussion, observed, that the observations which had been made in the meeting had been so fully answered by Mr. Bodmer and Mr. Wood that there was scarcely anything for him to reply to. Mr. Wood, in his further description of his own process of disintegrating slag, as compared with the Belgian method, observed, that the latter required more water, and that the water must be agitated. It was true that the Belgian process required a larger quantity of water, but it was also true that boys were employed to agitate the water both at its entrance to and at its exit from the stream of slag. Whatever difference there might be in the chemical composition of the two results, he (Mr. Nursey) was quite satisfied that there was very good slag sand produced in Belgium, though certainly not in the precise form in which Mr. Wood produced it.

Mr. WOOD said that the Belgian process required more water and extra labour.

Mr. NURSEY said that the labour was almost *nil*, being only that of two boys. However, the results were not so good as those produced in the machines he had described. He was

Fig. 2.

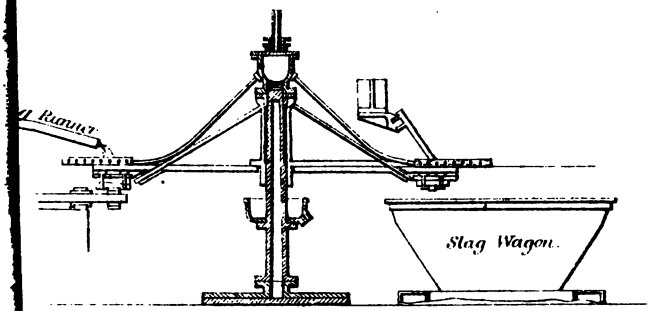


Fig. 4.

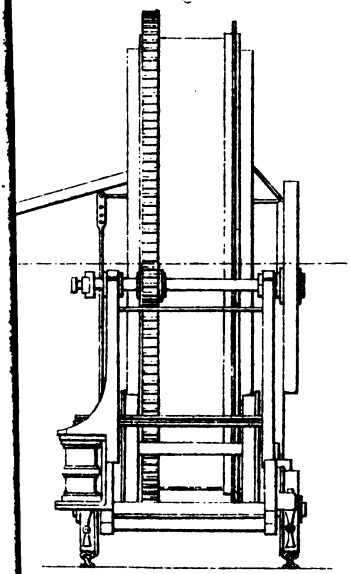
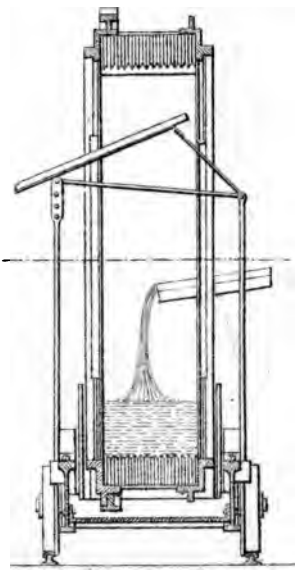


Fig. 5.



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unable to give particulars of the process of manufacturing cement in Belgium. He believed the method was kept very private, and he did not know whether the information was attainable. He had not been able to obtain it. He was glad to find that Mr. Wood had been so far able to solve the question of using slag successfully for agricultural purposes. Mr. Bell, both when Mr. Wood read his paper and when in Belgium, had stated that he could not obtain any results with it. Possibly Mr. Bell did not produce his slag in a condition fit for its application to the soil, or his land was not adapted for it. It would be very satisfactory to learn that there was a demand for slag in agricultural operations. That would be another means for getting rid of that vast accumulation which was now but waste.

The PRESIDENT said that he had used slag both as a cement and as a concrete, and he had certainly never found anything equal to it. There were some very excellent cements, such as Portland and Blue Lias lime, but the slag cement surpassed anything of which he had ever had experience, as regarded cements made in this country. He believed that the Italians had adopted the same method of utilizing iron slag—perhaps in another form—for many years, and their cement had been noted as being most solid and rock-like. After it had once set it was almost impossible to remove it without blasting. He had no doubt that in the course of time cement made of slag would arrive at the same condition. As regarded the bricks, he had a very high opinion of them, because for building purposes they resisted the action of damp. The stock bricks and kiln bricks were very absorbent, and hence in our humid atmosphere, unless we built a hollow wall, we had a damp interior. He believed that slag bricks were almost like fire bricks; and if they could be obtained at anything like the price which had been mentioned they were a most valuable acquisition. They would only need to be introduced to find their way into the hands of all engineers and contractors. Such persons would appreciate their good qualities, and award to the inventors that meed of praise and that support to which they were so justly entitled. It was also a matter which was well worthy of the consideration of all persons engaged in building operations. The present discussion might be the means of more fully introducing the invention in this part of the country. There were many things in the north of which we in the metropolis knew very little. He was very glad that the subject had been introduced to the Society, and he hoped that benefit would result both to the inhabitants of the south of England and to the inventors of the slag brick, which was produced from a material which had been for many years without any value whatever.

December 1*st*, 1873.

JABEZ CHURCH, PRESIDENT, IN THE CHAIR.

A NEW METHOD OF SETTING OUT THE SLOPES OF EARTHWORKS.

By CHARLES JULIAN LIGHT.

In the following brief paper the author desires to lay before the Society a method, which he believes to be new, of setting out the sidewidths of cuttings and embankments in sidelong ground. The conditions under which this operation has to be performed may be divided generally into three classes.

1. When the cross-section is practically level, say with an inclination of surface less than 1 in 100.

2. When the inclination of surface in cross-section is fairly uniform and exceeds 1 in 100.

3. When the cross-section is irregular and rough.

In cases of the first class, of course the process is perfectly simple, and in those of the third there is no better method than by taking cross-sections as often as required, plotting them and setting out the centre and slopes first upon paper. It is only with the second class therefore that the author proposes to deal. This is, however, a very large class, and probably includes more cases than both the others together, especially at the present day, when the use of sharper curves and steeper gradients leads to the practice of contouring round the shoulders of hills rather than cutting through their summits. The ordinary process may be described as tentative, the result being attained by a succession of approximations, the number of which, and, consequently, the speed of the operation, depend entirely upon the skill and experience of the engineer in charge. The operation itself is briefly as follows: Let the work to be set out be a railway cutting, through which the chain pegs of the centre line have been previously fixed and their levels taken. The engineer proceeds to measure horizontally from his centre peg, and at right angles to the centre line, a distance up the hill side such as his judgment leads him to expect will bring him to about the top of the slope at that point. Here he takes a level, and, adding the difference between it and that at the centre peg to the

sectional height at that point, he calculates therefrom the horizontal distance at which the slope would run out. This will, in all probability, not agree with the horizontal distance measured; he therefore takes another distance and a corresponding level, endeavouring to be, this time, rather beyond the true distance than not, if the first time he were short of it, or *vice versâ*, so that the true point, if not actually hit upon, may lie between his trial points. So he proceeds, with more or fewer trials according to his skill, until the exact point is found at which the top of the slope, as calculated from the height, coincides with the surface of the ground at the distance measured. The operation has then to be repeated for the lower side, and for each point at which sidewidths are required.

For this process of approximations the author aims at substituting a practically exact measurement along the surface of the ground, based upon data easily obtained, and deduced from tables of a simple form. The formula employed and the mode of arriving at it will be readily understood with the aid of the accompanying diagram, No. 1:

F being formation width from centre line,
F′ formation measured on ground,
H sectional height at centre line,
H′ sectional height at distance F,
S slope of cutting or embankment,
D difference of level on cross-section at a distance A from centre peg.

Let x = width of slope on surface.

Let y = difference of level between ground at distance F′ and at top of slope.

Then

$$\frac{\sqrt{x^2 - y^2}}{S} = H' \mp y$$

and

$$y = x\frac{D}{A}.$$

Substituting this value of y in the first equation we have

$$x\sqrt{1 - \frac{D^2}{A^2}} = S H' \mp x\frac{S D}{A}$$

$$x\left(\frac{\sqrt{A^2 - D^2}}{A} \pm \frac{S D}{A}\right) = S H'$$

$$x = \frac{A S H'}{\sqrt{A^2 - D^2} \pm S D}. \qquad (1)$$

Again, similarly,

$$H' = H \mp \frac{FD}{\sqrt{A^2 - D^2}},$$

and

$$F = F \frac{A}{\sqrt{A^2 - D^2}}.$$

For convenience, let $\sqrt{A^2 - D^2} = M$, then total sidewidth measured on surface

$$= F' + x = F\frac{A}{M} + AS\frac{H \mp \frac{FD}{M}}{M \pm SD}$$

$$= \frac{A}{M}\left(F + \frac{SHM \mp SFD}{M \pm SD}\right)$$

$$= \frac{A}{M}\left(\frac{FM \pm FSD + SHM \mp SFD}{M \pm SD}\right)$$

$$= A\frac{F + SH}{M \pm SD}. \qquad (2)$$

The diagrams (see Figs. 1, 2, 3, and 4) have been drawn for cuttings, but it is obvious that the same formula applies to embankments, the + sign in the denominator applying to the lower side in cuttings and the upper in embankments, and the − sign to the upper side in cuttings and the lower in embankments. The above formula includes all cases except those in which H is small, and is approaching the balance line. When $H' = 0$, or the formation width itself cuts out at the surface on the lower side in cuttings and the upper in embankments, as in diagram No. 2:

$$H = F\frac{D}{M} \text{ and } F = H\frac{M}{D}.$$

As x disappears on the lower side, sidewidth

$$= F' = A\frac{H}{D} = A\frac{\frac{H}{D}M - SH}{M - SD} = A\frac{F - SH}{M - SD}.$$

on the upper side, as before, sidewidth

$$= A\frac{F + SH}{M - SD};$$

and ∴ generally

$$= A\frac{F \mp SH}{M - SD}. \qquad (3)$$

When H on lower side $< F\frac{D}{M}$, as in Diagram No. 3, F′ remains of the same value as before, viz. $F\frac{A}{M}$, but is divided into two parts, of which

$$F'' = H\frac{A}{D}; \quad \therefore F''' = F\frac{A}{M} - H\frac{A}{D} = \frac{A}{D}\cdot\frac{FD - HM}{M}.$$

Then

$$H' = F'''\frac{D}{A} = \frac{FD - HM}{M},$$

and

$$(1)\ x = \frac{ASH'}{M - SD}$$

(the condition being now similar to that of the upper side)

$$= \frac{AS}{M - SD}\cdot\frac{FD - HM}{M};$$

and total sidewidth

$$= F' + x = \frac{FA}{M} + \frac{AS}{M}\cdot\frac{FD - HM}{M - SD}$$

$$= \frac{A}{M}\cdot\frac{FM - FSD + SFD - SHM}{M - SD} = A\frac{F - SH}{M - SD}.$$

On the upper side, the sidewidth remains, as before,

$$= A\frac{F + SH}{M - SD}.$$

Therefore $A\frac{F \mp SH}{M - SD}$ represents the value of the side widths for all conditions between $H' = o$ and $H = o$.

When $H = o$ (see diagram No. 2) both sides being, as in the last case, similarly conditioned to the upper side in the general case, the formula becomes

$$\frac{AF}{M - SD}. \qquad (4)$$

To recapitulate:

$$\text{The general value of sidewidth} = A\frac{F + SH}{M \pm SD}.$$

Its value between the conditions $H' = o$ and $H = o$; that is, when $H = \text{or} < \frac{DF}{M}$,

$$= A\frac{F \mp SH}{M - SD}.$$

Its value when $H = o$,

$$= \frac{AF}{M - SD}.$$

The most convenient value of A will be 100 feet, and as the factor in the above formula, which is not readily calculated, is $\sqrt{A^2 - D^2}$, a table of its values, A being 100 and D varying from 1 to 50, is supplied in a diagram, and is appended to the paper. In working directly from the formula, D^2 may be practically neglected in cases where $D < 10$ for the + sign, or 7 for the − sign, if the sectional height H be moderate. Thus, with a double line formation of 15 feet from the centre, slopes 2 to 1 and sectional height 10 feet, the result of neglecting D^2 and using $100\frac{F + SH}{100 \pm SD}$ as the formula will only be an error of about $1\frac{1}{2}$ inch in the sidewidth. It will, however, be readily seen that for the most effective use of the method now proposed, tables will be required, to save loss of time and risk of error from calculations in field. A specimen of the tables proposed is exhibited in Table No. 2, wherein are given the sidewidths for a double line formation of 30 feet, that is F = 15, with slopes $1\frac{1}{2}$ to 1, and for values of D from 1 to 10, and of H also from 1 to 10, A being 100. It will be at once understood that this would only form a small portion of the actual Table, but it is sufficient to show the arrangement and to illustrate the mode of use. It must also be remarked, that although A is taken = 100 feet as a basis for the tables, it does not follow that the difference of level D is always to be taken in practice at that distance from the centre peg. More correct results will be obtained by taking it at any even distance more nearly approximating to the final point required, and then reducing to the equivalent at 100 feet. If, for example, the difference be taken at 40 feet, the slope being expected to run out somewhere near that distance, and found to be 3·2 feet, it will only be necessary to look in the Table for the sidewidth corresponding to 8 feet, its equivalent at distance 100 feet.

This being premised, the practical working of the proposed method can be shown by one or two assumed cases. An engineer is setting out for a railway cutting, the formation width and slopes of which are as in the Table. His sectional height of cutting at the chain peg is 9 feet. He guesses the cross-slope of the ground to be about 1 in 20, and taking a level up the hill side, at right angles to the centre line, at a distance of 30 feet from the centre peg, measured on the surface of ground, he finds the difference between that point and the centre peg to be 1·80 feet, equivalent to 6 feet on 100. Referring to the Table, he finds at the intersection of H = 9 and D = 6 the value of the upper sidewidth to be 31·4, and sets out accordingly. Similarly, on the lower side, in case there should be any variation in the cross-slope of the ground, he takes a level down the hill side at a distance of, say, 25 feet from the centre peg, and finds the difference between that and the centre peg to be 2·0 feet, equivalent to 8 feet on 100 feet. At the intersection of H = 9 and D = 8 is found the value of the lower sidewidth, 25·5. The sidewidths thus found are exact, and all delay in making approximations and all possible errors in calculation are avoided.

Again, let it be supposed that sectional height of cutting is 1. A similar process will give 18·2 feet for the upper and 15·4 feet for the lower sidewidth—the latter having now cut out above ground and become an embankment. If the railway be in bank, instead of cutting, the process will be the same, "lower" being read for "upper," and *vice versâ*. But it will be objected that the sectional heights will hardly ever be even feet, and that, therefore, the correct value of the sidewidths will not be found in the Table. This is at once granted; but on inspection it will be seen that the differences between the sidewidths from one foot of H to another are so moderate that there will be no difficulty in deducing the value, true to a decimal of a foot, corresponding to any intermediate height, and this is all that can possibly be required in actual setting out. For example, if H = 9·27 feet, D being 8, and F and S as before, the values of the upper sidewidths for H = 9 and H = 10 are respectively 32·5 and 34·2. It then hardly requires calculation at all to see that the correct sidewidth will be 33·0. The differences for each foot of H, given in the Table at the bottom of the columns of sidewidths, will still further facilitate this correction.

A similar objection may be anticipated as to the values of D, but it has even less force, because the sidewidths corresponding to successive values of D are much closer than those corresponding to successive values of H, and the difficulty can be treated in a similar manner. If, for example, H = 9·27 and

D = 6·45, the values of the upper sidewidths for H = 9 and H = 10 (D being for the moment assumed = 6) will be 31·4 and 33·0. Therefore, that for H = 9·27 may be taken as 31·8. The increment from D = 6 to D = 7, H being 10, will be seen to be ·6, and the proportional increment for 6·45 is obviously ·3, making the corrected sidewidth 32·1. Now, if this particular case be rigidly worked out by the formula, the exact result will be found to be 32·07, so that the value obtained, it may almost be said by inspection, from the Table, is within ·03 of the true value, a difference quite inappreciable in setting out.

There remains, however, one further difficulty to deal with, viz. the variations in formation widths used in practice. Of course it is proposed to provide separate tables for all the chief formation widths in use; but not to multiply, unnecessarily, the number of tables, the means will be supplied with each of correcting for values of F, one foot more or less than that on which the Table is based. Above each value of D will be found a difference, which is that due to one foot of F, and which applies to the whole of that column of sidewidths; for the change in F affects to the same extent the sidewidths for all values of H, as the denominator remains unaltered, but has a different effect for each successive value of D. If, for instance, the sidewidths be required for a formation width from centre of 16 feet, it is only necessary to add to each tabular value the number placed at the top of its column. Similarly for 15 feet 6 inches, add half that number, and so on.

The series of Tables which the author proposes to construct will include the following:

I. A Table of values of $M = \sqrt{100^2 - D^2}$, for all values of D from 1 to 55, that is, for cross-slopes from 1 in 100 to 1 in $1\frac{1}{2}$.

II. A Table of values of H, when $H^1 = 0$, corresponding to successive values of D at the principal formation widths.

III. Tables of sidewidths for double line formation of 30 feet, that is, F = 15, and for slopes of $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, and $2\frac{1}{2}$ to 1 respectively. These Tables, as already explained, will also be easily applicable to formations from 28 feet to 32 feet.

V. Tables for the same slopes, adapted to values of F = 5 feet 6 inches and 9 feet 6 inches.

Table II. will be found useful in enabling the engineer, when setting out, to ascertain from his section the point where the half formation width cuts out on the surface, and where, consequently, there is a cusp, as it were, in the line of slope, on the upper or lower side respectively, where the balance line on that side occurs between the cutting and embankment.

Table V. will be required in the case of single lines of rail-

way, when the cuttings are set out one-sided, in anticipation of the line being afterwards doubled. Such a section is illustrated in diagram 4. The Table for F = 5 feet 6 inches will be based on values of H 6 inches less than the nominal ones, so that the sectional heights may be used without correction.

In the Tables for the flatter slopes it will be obviously unnecessary to carry the values of D to the same extent as in those for the steeper ones, such slopes being only employed in ground that would not naturally stand at a sharp inclination; but, on the other hand, it may be desirable in these cases to tabulate sidewidths for intermediate values of H and D. It will, of course, be understood that although reference has been made in this paper to railways only, the method and its Tables are equally applicable to all descriptions of earthwork, as for canals, roads, &c.

In conclusion, the author would observe that he has no expectation of the method he now advocates altogether superseding the one now in use, but offers it as one which he believes to have advantages, and which many may prefer to employ. He has endeavoured to meet such difficulties and objections as have suggested themselves.

TABLE No. 1.

D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	99·995	11	99·39	21	97·77	31	95·07	41	91·21
2	99·98	12	99·28	22	97·55	32	94·74	42	90·75
3	99·95	13	99·15	23	97·32	33	94·40	43	90·28
4	99·92	14	99·01	24	97·08	34	94·04	44	89·80
5	99·87	15	98·87	25	96·82	35	93·67	45	89·30
6	99·82	16	98·71	26	96·56	36	93·30	46	88·79
7	99·75	17	98·54	27	96·28	37	92·90	47	88·27
8	99·68	18	98·37	28	96·00	38	92·50	48	87·73
9	99·59	19	98·18	29	95·70	39	92·08	49	87·17
10	99·50	20	97·98	30	95·39	40	91·65	50	86·60

TABLE No. 2.

	H.	F = 15. S = 1½.																			
Diff. per ft. of F.		·99	1·01	·97	1·03	·95	1·04	·94	1·06	·93	1·08	·92	1·10	·90	1·12	·89	1·14	·88	1·16	·87	1·18
D =		1		2		3		4		5		6		7		8		9		10	
	0	15·3	15·3	15·4	15·4	15·7	15·7	16·0	16·0	16·3	16·3	16·5	16·5	16·8	16·8	17·1	17·1	17·4	17·4	17·8	17·8
	1	16·2	16·8	16·0	17·0	15·8	17·3	15·6	17·6	15·4	17·9	15·2	18·2	15·1	18·5	15·4	18·8	15·7	19·2	16·0	19·6
	2	17·7	18·3	17·5	18·5	17·2	18·8	17·0	19·2	16·8	19·5	16·6	19·8	16·3	20·1	16·1	20·5	15·9	20·9	15·7	21·3
	3	19·2	19·8	18·9	20·1	18·6	20·4	18·4	20·8	18·2	21·1	18·0	21·5	17·7	21·8	17·5	22·2	17·2	22·6	17·0	23·1
	4	20·7	21·4	20·4	21·7	20·1	22·0	19·8	22·4	19·6	22·8	19·3	23·1	19·0	23·5	18·8	23·9	18·5	24·4	18·3	24·9
	5	22·2	22·9	21·9	23·2	21·5	23·6	21·2	24·0	20·9	24·4	20·6	24·8	20·3	25·2	20·1	25·6	19·8	26·1	19·6	26·7
	6	23·6	24·4	23·3	24·7	22·9	25·1	22·6	25·6	22·3	26·0	22·0	26·4	21·7	26·8	21·4	27·3	21·2	27·8	20·9	28·4
	7	25·1	25·9	24·8	26·3	24·4	26·8	24·0	27·2	23·7	27·6	23·4	28·1	23·1	28·5	22·8	29·0	22·5	29·6	22·2	30·2
	8	26·5	27·5	26·2	27·8	25·8	28·2	25·4	28·7	25·1	29·2	24·8	29·7	24·5	30·2	24·2	30·7	23·8	31·3	23·5	32·0
	9	28·0	29·0	27·7	29·3	27·3	29·8	26·9	30·3	26·5	30·8	26·2	31·4	25·9	31·9	25·5	32·5	25·2	33·1	24·9	33·8
	10	29·5	30·5	29·1	30·8	28·7	31·3	28·3	31·9	27·9	32·5	27·6	33·0	27·2	33·6	26·8	34·2	26·5	34·8	26·2	35·5
		1		2		3		4		5		6		7		8		9		10	
Diff. per ft. of H.		1·5	1·5	1·5	1·5	1·4	1·6	1·4	1·6	1·4	1·6	1·3	1·6	1·3	1·7	1·3	1·7	1·3	1·7	1·3	1·8

DISCUSSION.

Mr. J. H. ADAMS said that he had experienced the difficulties pointed out by Mr. Light in setting out railway slopes, and was aware of the loss of time that occurred in finding the true width of the slope. That the Tables given by the author were correctly worked out did not admit of doubt, and he believed that the method would be of great advantage to engineers, and lead to a saving of time in carrying out such work. There was every probability of the Tables being very useful indeed to the practical engineer, in setting out railways, roads, and canals.

Mr. T. CARGILL said that he could not see any particular advantage in the method proposed by Mr. Light over that ordinarily employed in laying out the slopes of railways. It appeared to be a substitution of mathematical formulæ for ordinary plotting. He had laid out the sidewidths of many miles of railway by the usual mode adopted by engineers, which was perfectly accurate to within about three inches. The cross-section paper was ruled to a scale of 20 feet to the inch horizontally and vertically. The formation level, and the allowance for fences from the point where the slope of the railway intersected the embankment or cutting, was also given. In addition, in every case the longitudinal section must be made, and the depth of the cutting or the height of the embankment. The diagrams did not appear to refer to exceptional cases where the ground was irregular, but to slopes which were all uniform. He did not see how the author's method would meet cases where the ground was irregular. The only data required in laying out sidewidths was the depth and the height according to the embankment, and an accurate cross-section. Engineers made their cross-sections wherever they were required, according to the contour of the ground, whatever might be the distances adopted. From the cross-section paper they got the accurate horizontal distance, and they laid out the ground accordingly. He remembered the manner in which a young engineer, for the contractor, laid out the sidewidths of a railway some years ago. He had a kind of triangle of ropes and small pulleys, and, having got the Table of sidewidths from the office, he plumbed the sidewidths all along the line, first on one side, and then on the other. He had, of course, the accurate horizontal distance given to him, but he never thought of making any calculation, and yet the land was accurately laid out. He (Mr. Cargill) thought that the Tables themselves would be valuable, but he did not see how they were to be applied in

practice. The process of giving the assistant the Table of side-widths was very simple. He did not see how Mr. Light would apply his Tables all along a section of country, without giving more trouble than the ordinary method gave, and he did not see the advantage to be gained by using the new method.

Mr. J. H. ADAMS said it appeared to him that Mr. Cargill was arguing cases that were not put by Mr. Light. The new method was supposed to apply to cases where cross-sections were not taken, and such frequently occurred. He had had them in his own experience. For instance, the longitudinal section or level might have been altered, or the line might have been diverted. There might be sections, such as Mr. Cargill had indicated, to which the Tables would not apply, and then other rules would have to be resorted to; but the Tables would be useful for a regular section, and with the inclination of the ground within the limits Mr. Light had proposed.

Mr. CARGILL asked Mr. Adams whether he meant that a railway was to be laid out without the height of the embankments or the depth of the cutting being known. He did not know whether Mr. Adams meant to lay out his sidewidths before he had got his gradients. If so, he (Mr. Cargill) did not know where they would go. In fact, the line could not be laid out, for according to Mr. Light's formula they must have the vertical height. If Mr. Adams meant that they were to lay out the sidewidths before they had got the depths of cutting, he was probably right as to the utility of the new method.

Mr. J. H. ADAMS said that he referred to cases in which the gradients of a line had been altered after the longitudinal section had been taken. On sidelong ground the depth of the cutting would be altered, from the fact of a line being diverted from the original course.

Mr. F. W. BRYANT asked whether Mr. Adams would not have a longitudinal section taken of that alteration?

Mr. ADAMS said that he had met with cases where that had been omitted. Sometimes a curve had been altered to avoid certain property.

Mr. F. W. BRYANT said that if the deviation was only a slight one, engineers could measure from the original pegs, and then read off very easily on their section paper.

Mr. CARGILL said that if Mr. Adams meant that they altered their line and altered their longitudinal section, they would then have to do the whole work over again.

Mr. ADAMS said that he did not mean that both alterations occurred together, but sometimes there was one, and sometimes the other.

Mr. CARGILL asked Mr. Light how he would apply his

method if a house came in the way. With a cross-section engineers could get their point. Until they got their side-widths they did not know whether they were to take the house or not.

Mr. ADAMS said that the ground was generally pretty uniform where houses were built.

Mr. USILL said he agreed with Mr. Cargill that there was nothing like the old system. The most important thing in setting out a railway was to have the centre line properly staked out at first. That being done, of course the longitudinal section was taken, and then cross-sections. The work was then a very simple matter, unless there was any great deviation. One of the reasons why he should strongly adhere to the old system was, that it was very important in all railway work to have a record of the ground before it was disturbed, not only that the engineer might be able to find any point at a future time, but in case of a dispute with the contractor as to the work which he executes. It was very well for engineers to have a method in their waistcoat pockets by which they could find the required point at a minute's notice. No doubt the Tables were valuable, and tabular methods were now coming largely into use, and greatly facilitated the operations of the engineer; but he was bound to say that he did not expect that they would supersede the processes already in existence, and he did not see how Mr. Light's Tables were to be preferred to the old cross-section method.

Mr. OLANDER said that about twelve years ago he was engaged on such work, and at that time the system adopted in getting the halfwidths on railways was a tentative measure. He presumed that that was the measure Mr. Light mentioned as the original mode. It was a very troublesome method, and he had often thought, when he was using it himself, that it would be a good thing if a method of measuring directly the slope on either side was invented. It was impossible for him to follow Mr. Light's formulæ as they were read; but if his method was to measure directly from the centre line to the proposed width, it would do away with the original tentative method, and in that way would be a very great improvement. There was an instrument invented by Mr. Lister about twelve years ago. It was in the form of a theodolite; in fact, it was a theodolite with certain additions. The inventor took the correct half-widths of one section only, and on that section he placed his theodolite. The top of the instrument was so arranged that it could radiate to the proposed angle of the slope. Consequently, if fixed correctly on the cross-section, the instrument could sweep the sidelong ground, so that the line formed by the

intersection of the wires in the theodolite and the ground would be the correct halfwidth. That theodolite was exhibited at a *soirée* of the Institute of Civil Engineers about the time of its invention, and he (Mr. Olander) thought it a great improvement. If Mr. Light's method would do away with the tentative process, and give approximately correct results, it would be very valuable, especially for young engineers.

Mr. CARGILL said that he had seen the instrument invented by Mr. Lister, and also an older instrument invented by Sir John MacConnell. With the latter instrument they had either to find or to assume the angle of slope, and sometimes there were five or six angles of slope. He would advise young engineers to have nothing to do with instrumental methods.

Mr. LIGHT, in reply, said that he had anticipated from the character of the paper that the discussion could be only a short one, but he thought that it might be desirable to bring the subject before the Society, and have their opinion upon it. With regard to the remarks of Mr. Cargill and Mr. Usill, he might say generally that with the system of taking cross-sections he had no comparison to make. Of course that was the superior and right method, but as a matter of fact it was not generally adopted; and, as distinctly stated in the paper, it was only in lieu of the ordinary tentative method that he proposed the system now described. That would answer Mr. Cargill's question as to houses being in the way. It was quite clear that in exceptional cases like that, any engineer would necessarily take cross-sections and plot them. On one point Mr. Cargill must have some little misconception. In order to avoid confusing the diagram, he (Mr. Light) had given D and A as taken only in one direction. It was by no means necessary that they should be so taken; and in the instance which he gave in the paper they were taken in both directions. Therefore the proposed method could meet the cases of considerable variation of the slope. Although it was quite understood by the paper that he did not intend the method to be specially applicable to anything except regular rolling slopes, at the same time he believed that he should have no difficulty whatever in using it in rougher ground. Unless that irregularity was very severe indeed, the error of the slope from the centre peg would be but small. The Tables, after a little experience with them, would guide the engineer so closely as to where he was likely to come out, that his error could not be great, and at the very worst he would get a quicker result than by the old tentative system, for the second approximation would almost certainly bring him to the point.

Mr. CARGILL said that he was not supposing a case in which

there was any uniform fall, but one where there was a rise first and a fall afterwards.

Mr. LIGHT said that of course such a case as that would necessitate a cross-section, and he believed that he stated that very clearly in the paper. With regard to the practical remarks that had been made by Mr. Usill, upon the value of cross-sections, no one could have any question that they were most important as a record of the work; but he repeated that in very many cases cross-sections were taken only where the ground was severe and difficult. The use made by Mr. Lister of the theodolite, as described by Mr. Olander, was very similar to the look which an engineer naturally gave to the poles after he had set out the slopes, to see that the sweep was fair and true; only the one examination would be for the purpose of setting the poles, and the other for the purpose of correcting them after they were set.

The PRESIDENT said that Mr. Light had given a paper of considerable value, and one with which he had evidently taken a great deal of trouble. Of course there was a great difficulty in following the diagrams and formulæ during the reading of the paper, and hence it was impossible to give it that discussion to which it was fairly entitled. But one result of the discussion seemed to be, that important as were the uses of the cross-section method, it was admitted that Mr. Light's system as an auxiliary was also of great value. Therefore, the combination of Mr. Light's method with the old system might be very useful. The Society of Engineers was very much indebted to Mr. Light for the study he had given to the subject. Mr. Light was very accurate in all his calculations, and they might rely upon it that anything he advanced was trustworthy and reliable.

THE END.

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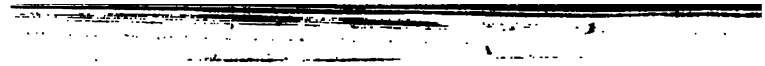

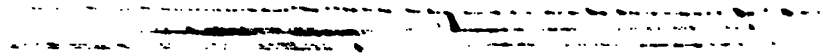

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